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QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT,
CRANE, INDIANA ②

176 715-1

2. EVALUATION PROGRAM
FOR
NICKEL CADMIUM SEALED CELLS —
GENERAL PERFORMANCE TEST
OF
GOULD-NATIONAL BATTERIES, INC.
20.0 AMPERE HOUR CELLS

QE/C 64-4

28 February 1964

(NASA Order W-11252-B)

(NASA-W-11252-B) - index

(NASA CR-53639; QE/C-64-4) OTS: See cover

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

REPORT BRIEFSEALED NICKEL CADMIUM BATTERY PROGRAMOFCELLS DESIGNED FOR USE IN SPACECRAFT

- Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961
(d) National Aeronautics and Space Administration Preliminary Specification "Environmental Exposures and Tests for Subassemblies of International Ionosphere Satellite S-51" of 7 February 1961
(e) MIL-E-5272C(ASG) Amendment 1

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of Sealed Nickel Cadmium Cells was begun according to the program outline of reference (c). References (d) and (e) are Environmental Test Specifications.

B. The object of this evaluation program is to gather specific information concerning sealed nickel cadmium cells designed for use in spacecraft. Information concerning the performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power system designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. A total of 1100 cells was purchased by National Aeronautics and Space Administration (NASA) from four manufacturers, and consist of seven sample classifications ranging from 3 to 20 ampere hours.

D. The program is divided into three main sections consisting of Acceptance Tests, General Performance Tests and Cycle Life Tests.

E. This report is the fifth of a series of seven of the General Performance Test Section. It gives the results of the characterization tests of five 20.0 ampere hour size cells supplied by Gould-National Batteries, Inc., St. Paul, Minnesota. The cells are rated at 20.0 ampere hours by the manufacturer.

II. SUMMARY OF RESULTS.

A. The cells were capable of withstanding the Vibration, Mechanical Shock and Acceleration requirements.

B. Temperatures below and above 25° C. imposed the primary limitations on the charge acceptance and the discharge capacity of the cells.

1. At 25° C. the on charge voltage reached the maximum limit of 1.50 volts/cell at the c/10 charge rate on only one cell at approximately 82 percent of the charging period and then dropped below the limit at about 92 percent of the charging period. However, at the c/5 rate, two of the five cells reached the maximum limit at about 70 percent of charge on some of the recharges, whereas, the remaining three cells reached the limiting voltage at about 85 percent of charge on some of the recharges. A comparison of the discharge capacities, when preceded by charges at the c/10 or c/5 rates, show that the discharge capacity at the c/5 rate showed very little difference when previously charged at the c/10 or c/5 rates. However, at the c/2 rate, the discharge capacity was about seven percent higher when preceded by the lower rate of charge at c/10.

2. At 0° C. the on charge voltage reached the maximum limit of 1.50 volts/cell at about 50 to 60 percent of the charging period on about 50 percent of the recharges at the c/10 and c/5 charging rates. The discharge capacities measured at the c/5 rate, when preceded by a charge at the c/5 rate, averaged 12 percent below the like capacities measured at 25° C. Similarly, when preceded by a charge at the c/10 rate, the capacities averaged 20 percent below their 25° C. capacities. The discharge capacities measured at the c/2 rate, when preceded by a charge at the c/5 rate averaged 15 percent below the like capacities measured at 25° C. Likewise, when preceded by a charge at the c/10 rate, the capacities averaged 20 percent below their 25° C. capacities.

3. At 50° C. the on charge voltage never reached the maximum limit of 1.50 volts/cell. The charge rate in combination with discharge rates appeared to have an additional or secondary influence on the discharge capacity of the cells. The capacities of the cells measured at the c/5 rate averaged 22 percent less when previously charged at the c/5 rate than when previously charged at the c/10 rate. Likewise, the capacities of the cells measured at the c/2 rate averaged 17 percent less when previously charged at the c/5 rate than when previously charged at the c/10 rate. The capacities of cells at c/5, when previously charged at the c/5 rate, averaged 43.1 percent of the capacities at 25° C., whereas, the capacities when previously charged at c/10 averaged 49.1 percent of those measured at 25° C.

C. The cells at 0° C. were incapable of accepting a continuous overcharge at a rate of c/10 or higher as the maximum on charge voltage limit of 1.55 volts/cell was reached prematurely. Indications are that at 25° C.

and 50° C. the cells are capable of withstanding overcharges as high as the c/4 rate without excessive temperature rise although one cell reached the voltage limit at the c/8 rate. One of the cells at 50° C., was overcharged successfully at the c/1 rate. The overcharge sequence began with the c/10 rate and was increased by steps to the c/1 rate, after stabilization of voltage at each preceding charge rate. It is questionable whether the cells could have been overcharged at the c/4 rate when applied initially to a fully charged cell without reaching the maximum voltage limit of 1.55 volts per cell before voltage stabilization.

D. Charging efficiency was limited by temperature.

1. At 0° C: the voltage limit of 1.50 volts/cell was reached at each charge rate at approximately the "knee" of the curve with the exception of the two cells at the c/1 rate which limited before the "knee" was reached. The maximum capacity of all cells at all charging rates ranged from 83 to 98 percent of their actual capacities of the acceptance tests at 25° C.

2. At 25° C. the voltage limit was reached on all charging rates with the exception of c/24. At the c/16, c/10 and c/5 rates, the maximum on charge voltage limit was reached when the cells had received from 100 to 120 percent of their rated capacity recharge. At the c/1 rate, the cell limited at 70 percent of the rated capacity recharge. At the c/24, c/16, c/10 and c/5 charging rates, the maximum discharge capacity was reached at approximately 125 to 150 percent of the rated capacity recharge. When preceded by a c/1 charge rate, the maximum capacity was reached at approximately 400 percent of the rated capacity recharge. The maximum capacities of the cells following all charging rates varies from 83 to 89 percent of the acceptance test capacities.

3. At 50° C. the voltage limit of 1.50 volts/cell was reached only at the c/1 rate where it limited at 40 to 50 percent of the rated capacity recharge. The inefficiency of the charge acceptance at 50° C. at the c/24, c/16, c/10 and c/5 charge rates allowed a maximum discharge capacity, in terms of acceptance test capacities, of only 40 percent following the c/16 charging rate, to 58 percent following the c/5 charging rate. The maximum capacities of the cells charged at the c/1 rate, with 200 percent rated capacity overcharge, was 60 to 72 percent of the acceptance test capacities.

RESULTS OF GENERAL PERFORMANCE TESTS
OF
20.0 AMPERE HOUR SEALED NICKEL CADMIUM CELLS
MANUFACTURED BY
GOULD-NATIONAL BATTERIES, INC.

I. INTRODUCTION.

A. On 10 July 1963, this activity began the General Performance Tests on five cells, following completion of the acceptance tests of the 200 cells. The general performance tests were completed on 15 November 1963.

B. The five cells chosen for the general performance tests consisted of two with actual capacities above the average of the 200 accepted cells, one with capacity approximately equal to the average, and two with capacities below the average.

II. TEST CONDITIONS.

A. The general performance or characterization tests were performed at existing relative humidity and atmospheric pressure and at three specific temperatures. The tests and test temperatures were as follows:

1. Vibration Test at room ambient temperature.
2. Mechanical Shock Test at room ambient temperature.
3. Acceleration Test at room ambient temperature.
4. Charge and Discharge Voltage versus Time at 0° C., 25° C., and 50° C.
5. Overcharge Characteristics at 0° C., 25° C., and 50° C.
6. Charging Efficiency at 0° C., 25° C., and 50° C.

B. All charging was by modified constant current with a voltage limit. All discharges were constant current.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. The five cells used for these tests were picked from the 200 cells in the acceptance test section. The capacity of cells 13 and 27 was above the average of the 200 cells, cell 72 approximated the average capacity and cells 74 and 77 were below the average capacity.

B. The 20.0 ampere hour cells, as received, were rectangular in shape with an average height (base to top of positive terminal), length and width of 7.95, 0.97 and 3.05 inches respectively. The average weight was 1045.0 grams. The cells, equipped with pressure relief valves instead of being sealed as specified, were returned to the manufacturer to be sealed after completion of the acceptance tests. The manufacturer sealed the cells by encasing each individual cell in a mold of epoxy resin. The average height (base to top of positive terminal), length and width is now 8.10, 1.49 and 3.56 inches respectively. The average weight is 1423 grams.

C. The cell container or can, and the cell cover are made of stainless steel. Both terminals are insulated from the can by a nylon seal and protrude as 1/4 - 28 threaded posts.

IV. TEST PROCEDURES AND RESULTS.

A. Sinusoidal Vibration Test.

1. Each cell, fully charged, was individually mounted in a rigid test fixture attached to the table of a M. B. Electronics Model C-10 vibrator. The amplitude or acceleration was monitored on the test fixture near the mounting points.

2. Each cell in turn, was then subjected to the sinusoidal vibration test conditions given in paragraph 3.2.4.1.2.1 of reference (d), which stated that the applied frequency shall be swept from the lowest to the highest frequency, once for each range and for each axis specified in the following schedule.

SINUSOIDAL SWEEP SCHEDULE

<u>Frequency Range - cps</u>	<u>Test Time Minutes</u>	<u>Acceleration g, 0 - to - Peak</u>
10 - 50	1.66	2.3 (a)
50 - 500	1.66	10.7
500 - 2000	1.00	21.0
2000 - 3000	0.30	54.0
3000 - 4500	<u>0.36</u>	21.0 (b)
	5.00 Min. Each Axis	

NOTES: (a) Within maximum amplitude limit of vibration exciter.
(b) Within maximum frequency limit of vibration exciter.

3. During the applied vibration, the cells were discharged at a rate of c/5 amperes. The discharge current and terminal voltage were monitored for evidence of cell malfunction during applied vibration. After the vibration test, the cells were visually examined for evidence of mechanical damage and checked by litmus paper for electrolyte leakage.

B. Random Motion Vibration.

1. Following the sinusoidal vibration, each cell was subjected to gaussian random vibration applied to each axis with the "g-peaks" clipped at three times the root-mean-square acceleration specified in the schedule. The vibration was applied successively to the Z-Z, X-X, and Y-Y axes. With the cell installed, the control accelerometer response was equalized with peak-notch filterization such that the specified power spectral density (PSD) values were within ± 3 db throughout the frequency band.

RANDOM VIBRATION SCHEDULE

Frequency Range cps	Test Duration Minutes	PSD Level g ² /cps	Approximate Acceleration g-rms
20 - 2000	4 Each Axis	0.07	11.5 (a)

NOTE: (a) Within amplitude limit of vibration exciter.

2. There were no failures of the five cells subjected to the vibration tests.

C. Mechanical Shock Test.

1. Each cell was charged at c/10 rate for 16 hours following the vibration test.

2. Each fully charged cell was mounted in a rigid test fixture. The fixture and the cells were mounted on the Barry Type 16805 Shock Machine. Each cell was subjected to 18 impact shocks as outlined in Procedure V, paragraph 4.15.5.1 of Specification MIL-E-5272C(ASG), reference (e), except that 40 G (for 11 ± 1 milliseconds) was used in lieu of 15 G. Three shocks were applied in each direction of each of the three mutually perpendicular axes of the cells.

3. During the shock test, the cells were discharged at a rate of c/5 amperes. The discharge current and terminal voltage were monitored at the moment of impact for evidence of malfunction of any cells.

4. At the conclusion of the test, the cells were examined for mechanical damage and checked with litmus paper for electrolyte leakage.

5. There were no failures of the five cells subjected to the mechanical shock tests.

D. Acceleration Test.

1. Each cell was charged at c/10 rate for 16 hours following the mechanical shock test.

2. Each fully charged cell was mounted in a rigid fixture attached to the Genisco Model C-159 Centrifuge. The cell was then subjected to the acceleration test conditions specified in paragraph 3.2.5.1.2 of reference (d). Accelerations were in the order listed below:

<u>Axis Direction</u>	<u>Acceleration Gravity Units (G)</u>	<u>Duration Minutes</u>
+Z	28.0	5.0
±Y +X	4.0	3.0
-X	12.0	0.5

3. During the acceleration tests, the cells were discharged at a rate of c/5 amperes. The discharge current and terminal voltage were monitored for evidence of cell malfunction during the acceleration test periods.

4. At the conclusion of the tests, the cells were examined for mechanical damage and checked with litmus paper for electrolyte leakage.

5. There were no failures of the five cells subjected to the acceleration tests.

E. Charge and Discharge Voltage Versus Time.

1. The five cells, each with a thermocouple attached to the positive terminal, were placed in a temperature chamber and allowed to stabilize at 0° C.

2. The five cells were subjected to the charge and discharge sequence listed below:

<u>Charge</u>	<u>Discharge</u>	<u>No. of Cycles</u>	<u>Temperature</u>	<u>Data</u>		<u>Charge Voltage</u>
c/10 - 16 Hrs	c/5 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Limited to Temp. 1.5 V/Cell
c/10 - 16 Hrs	c/2 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Limited to Temp. 1.5 V/Cell
c/5 - 8 Hrs	c/5 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Limited to Temp. 1.5 V/Cell
c/5 - 8 Hrs	c/2 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Limited to Temp. 1.5 V/Cell

* Cell temperature measured by thermocouple.

** Each cell was subjected to two or more charge-discharge cycles, until repeatability of data was satisfactory.

3. Upon completion of the above sequence, the tests were repeated for 25° C. and 50° C. ambient temperature conditions.

4. The results are shown graphically with cell charge and discharge voltages versus time as a function of rate of charge, rate of discharge and ambient temperature on Figures 1 through 20. Figure 21 is a graphic summary of the data of Figures 1 through 20.

5. There were no cell failures during any portion of these tests.

F. Overcharge Characteristics.

1. The five discharged cells were allowed to stabilize at 0° C. The cells were then subjected to the overcharge sequence listed below:

- a. Charge at c/10 for 16 hours.
- b. Charge at c/10 until the cell voltage stabilizes.
- c. Charge at c/8 until the cell voltage stabilizes.
- d. Charge at c/6 until the cell voltage stabilizes.
- e. Charge at c/4 until the cell voltage stabilizes.
- f. Charge at c/2 until the cell voltage stabilizes.
- g. Charge at c/1 until the cell voltage stabilizes.

2. Upon completion of the above sequence, the tests were repeated for 25° C. and 50° C. ambient temperature conditions.

3. On all tests, the voltage limit was 1.55 volts per cell and the cell temperature limit was 77° C. Exceeding either limit terminated the test at that temperature.

4. Table I shows the cell temperature as compared to the ambient temperature at the voltage stabilization point of each charging rate. Where "voltage limited" is noted, the cell voltages increased to the limiting value of 1.55 volts at the c/10 charging rate without reaching a stabilization point.

5. The results are shown graphically on Figure 22 as a plot of the cell voltage versus the log of the charging current.

6. Although the 0° C. sequence was terminated by the 1.55 volts per cell limit at the c/10 rate, there were no cell failures on any portion of these tests.

G. Charging Efficiency.

1. At the completion of the overcharge characteristics sequence, the cells were discharged at the c/2 rate to 1.0 volt per cell.

2. The five cells were then divided into three groups as follows:

a. One group of two cells (one above average and one below average) to be tested at 0° C. \pm 2° C.

b. One group of one cell (average cell) to be tested at 25° C. \pm 2° C.

c. One group of two cells (one above average and one below average) to be tested at 50° C. \pm 2° C.

3. At each temperature, the charging efficiencies of each of the five charging rates, c/10, c/24, c/16, c/5 and c/1, were determined by a series of charges at each given rate at designated increased time periods followed by discharges to 1.0 volt per cell until the charge ampere hours versus the discharge ampere hours indicated the "knee" had been reached and verified as shown in Figures 23 through 27. The duration of the initial charge at each rate was one-half of the number of hours required for 100 percent charge.

4. A normalizing cycle consisting of a c/5 charge for 8 hours and a c/2 discharge to 1.0 volt was given all cells after each set of charge rate tests before proceeding to the next series.

5. A sample run for the $c/10$ charging rate was as follows:

- a. Recharged at $c/10$ for 5 hours.
Discharged at $c/2$ to 1.0 volt.
- b. Recharged at $c/10$ for 6 hours.
Discharged at $c/2$ to 1.0 volt.
- c. Recharged at $c/10$ for 7 hours.
Discharged at $c/2$ to 1.0 volt.
- d. Recharged at $c/10$ for "X" hours.
Discharged at $c/2$ to 1.0 volt.

NOTE: X = number of hours necessary to indicate that the "Knee" of the Charge Ampere Hours versus Discharge Ampere Hours has been reached.

APPENDIX

I. Table I shows the cell temperatures as compared to the ambient temperatures at the stabilizing point of each charging rate.

II. FIGURES.

A. Figures 1 through 20 are graphs showing charge and discharge voltages versus time as a function of rate of charge, rate of discharge and ambient temperature.

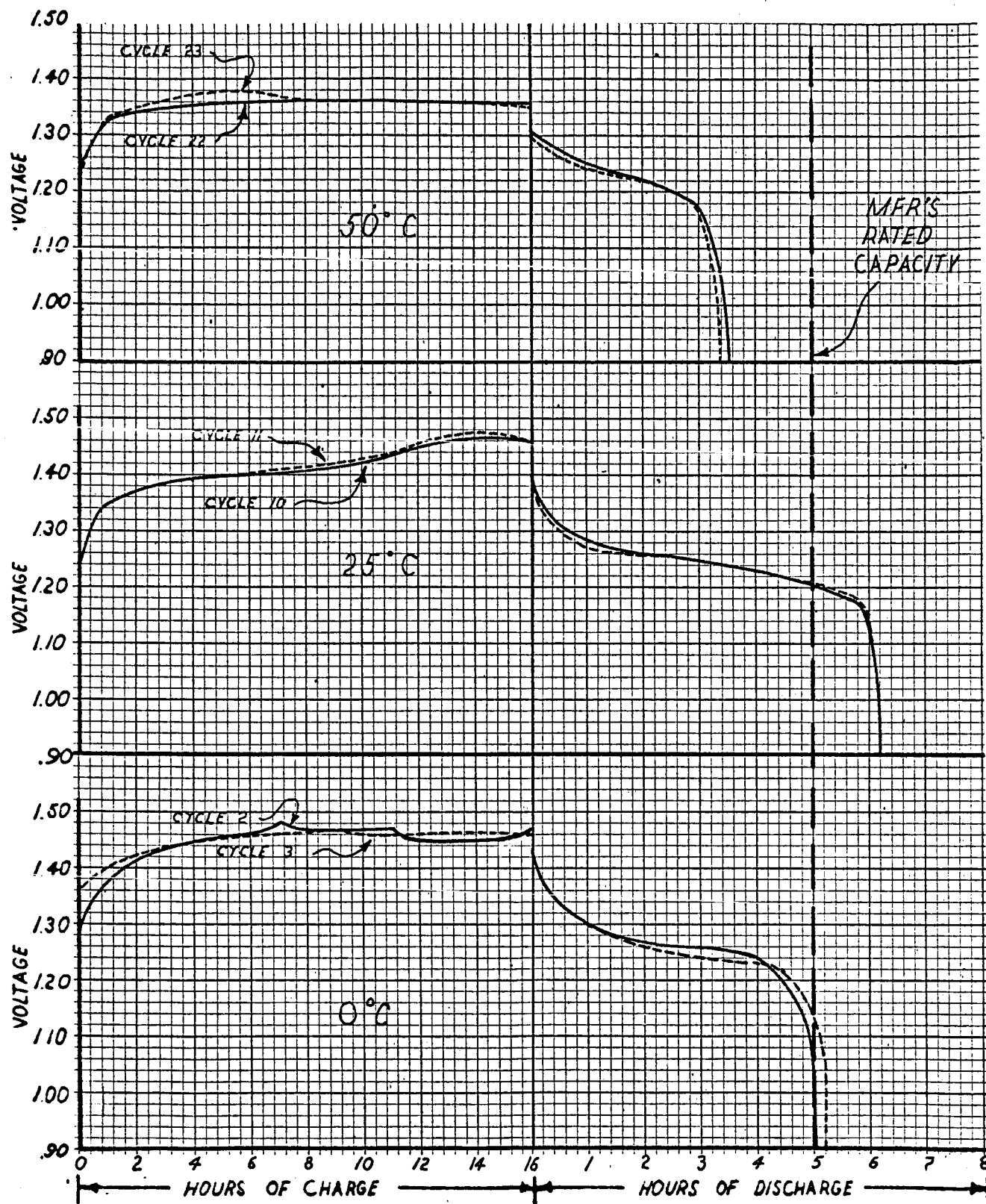
B. Figure 21 is a graphic summary of the data of Figures 1 through 20.

C. Figure 22 is a graph showing overcharge characteristics.

D. Figures 23 through 27 are graphs showing the charging efficiencies as a plot of charging ampere hours versus discharging ampere hours.

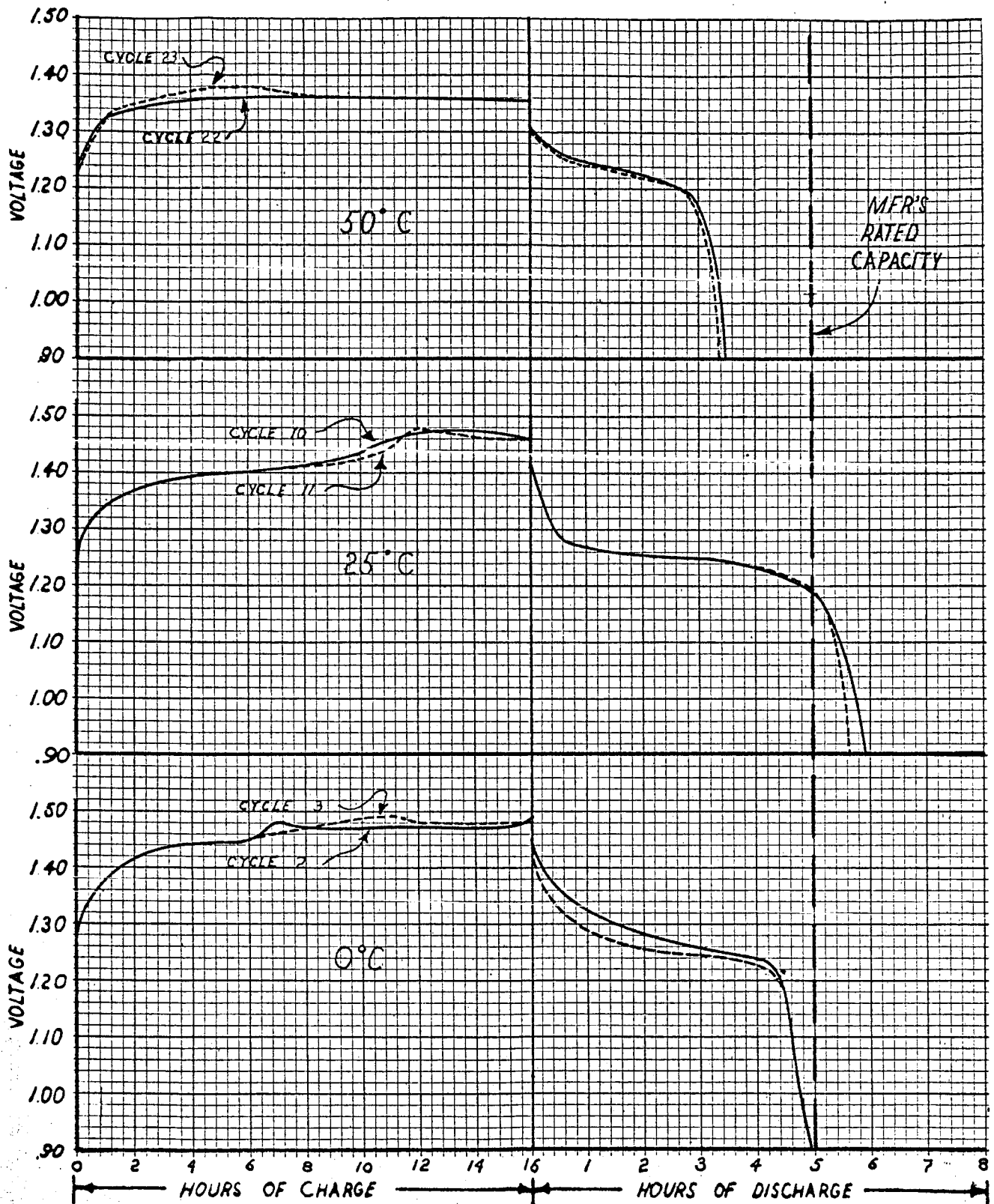
TABLE I

Cell Number	Ambient Temperature	Stabilizing Temperature (° C.)					
		c/10 Charge	c/8 Charge	c/6 Charge	c/4 Charge	c/2 Charge	c/1 Charge
13	0° C.	- - - - - VOLTAGE LIMITED - - - - -					
27	0° C.	- - - - - VOLTAGE LIMITED - - - - -					
72	0° C.	- - - - - VOLTAGE LIMITED - - - - -					
79	0° C.	- - - - - VOLTAGE LIMITED - - - - -					
77	0° C.	- - - - - VOLTAGE LIMITED - - - - -					
13	25° C.	30.6	28.3	27.8	31.1	56.1	76.7
27	25° C.	32.8	30.6	- - - - VOLTAGE LIMITED - - - -			
72	25° C.	33.3	31.1	32.8	36.7	66.1	78.9
79	25° C.	33.9	31.1	33.9	39.4	69.4	76.7
77	25° C.	32.2	29.4	32.2	37.8	62.8	76.7
13	50° C.	55.0	55.6	57.2	60.6	68.9	73.3
27	50° C.	56.1	57.2	60.6	66.7	75.0	81.1
72	50° C.	56.1	58.3	61.1	66.7	75.6	80.0
79	50° C.	56.7	59.8	61.7	68.3	72.2	80.0
77	50° C.	56.1	57.2	60.0	65.6	68.9	77.8



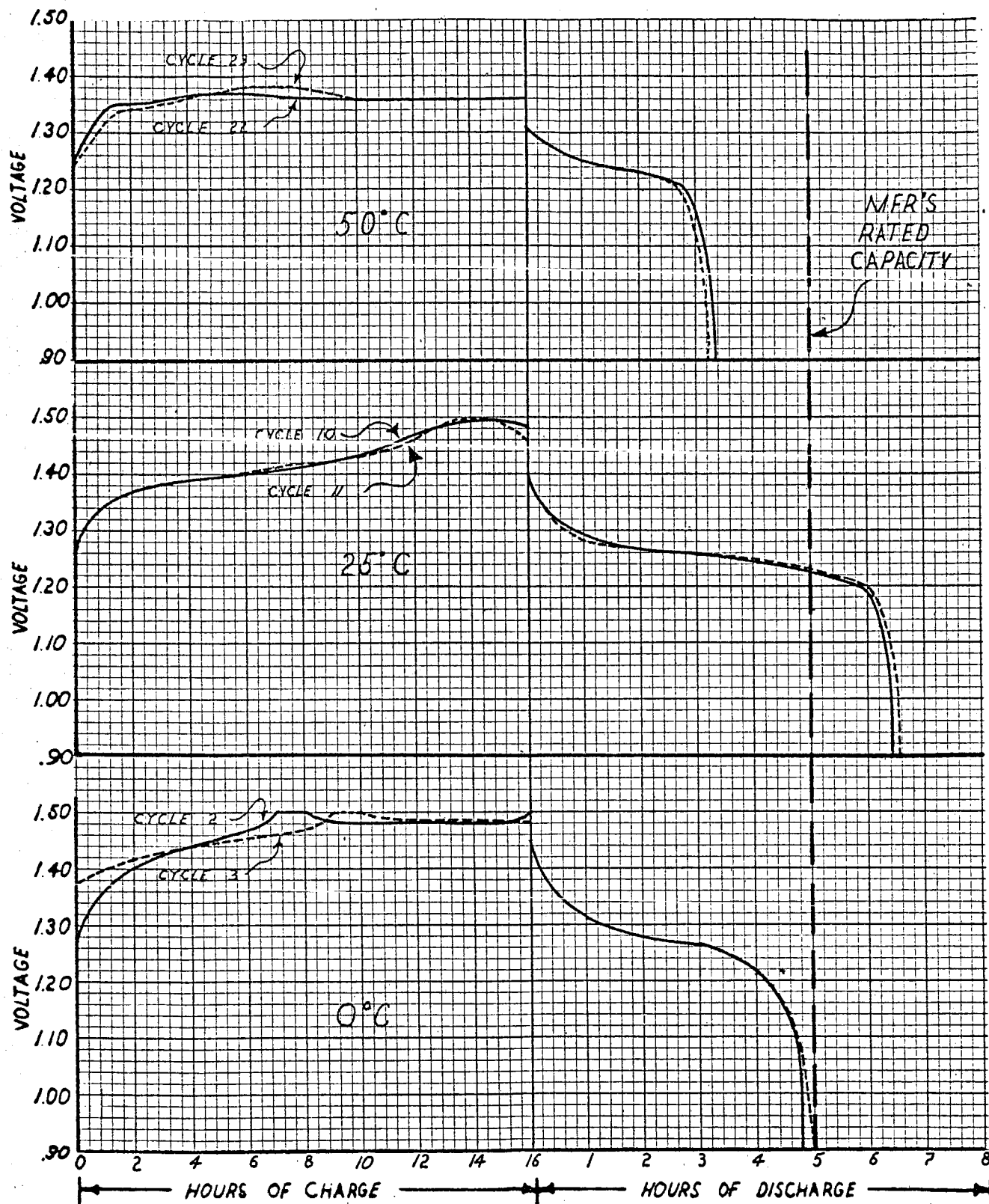
GOULD 20 A.H. CELL No. 74 NAD CRANE CAPACITY 22.2 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 1



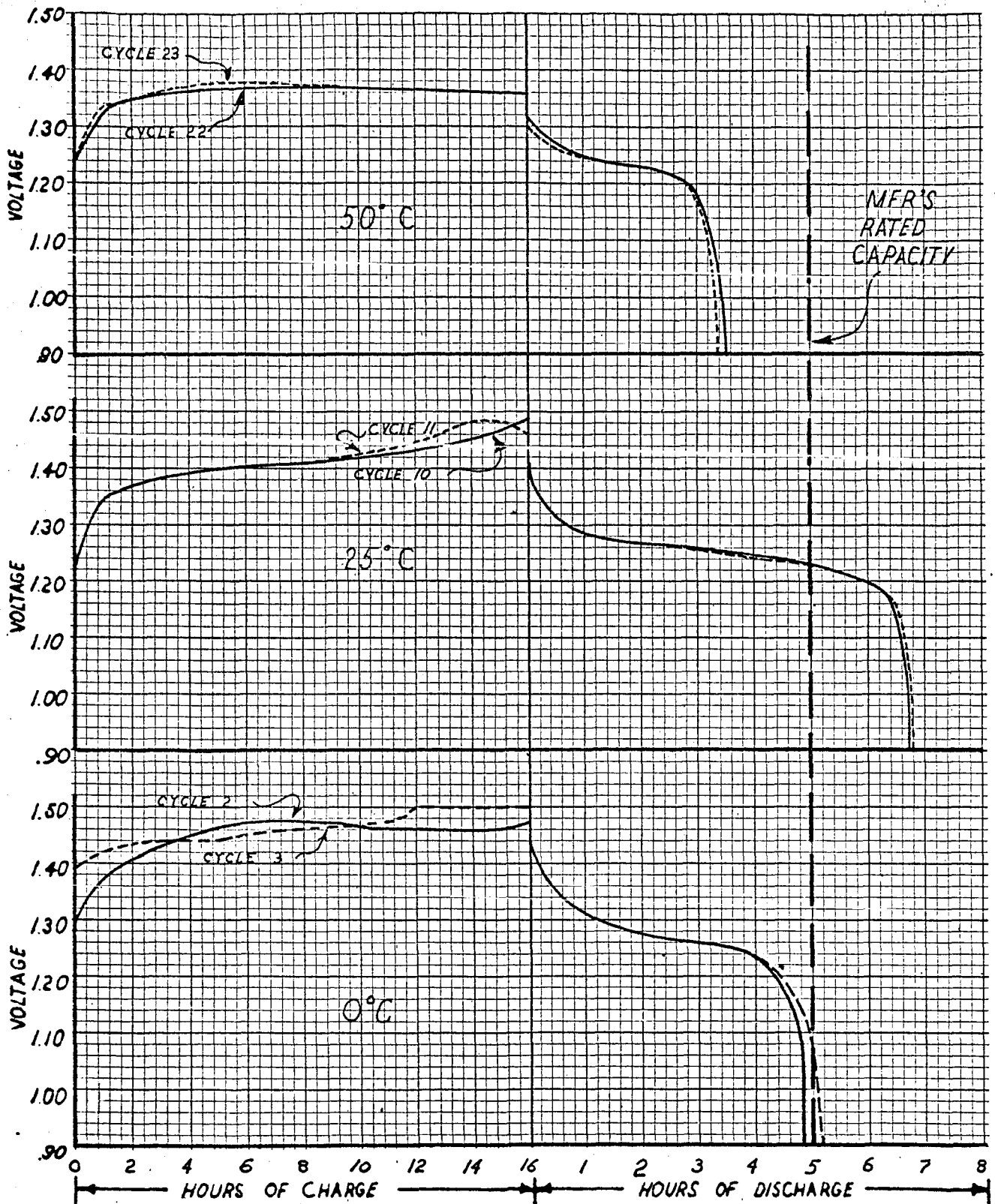
GOULD 20 A.H. CELL NO. 77 NAD CRANE CAPACITY 22.3 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 2



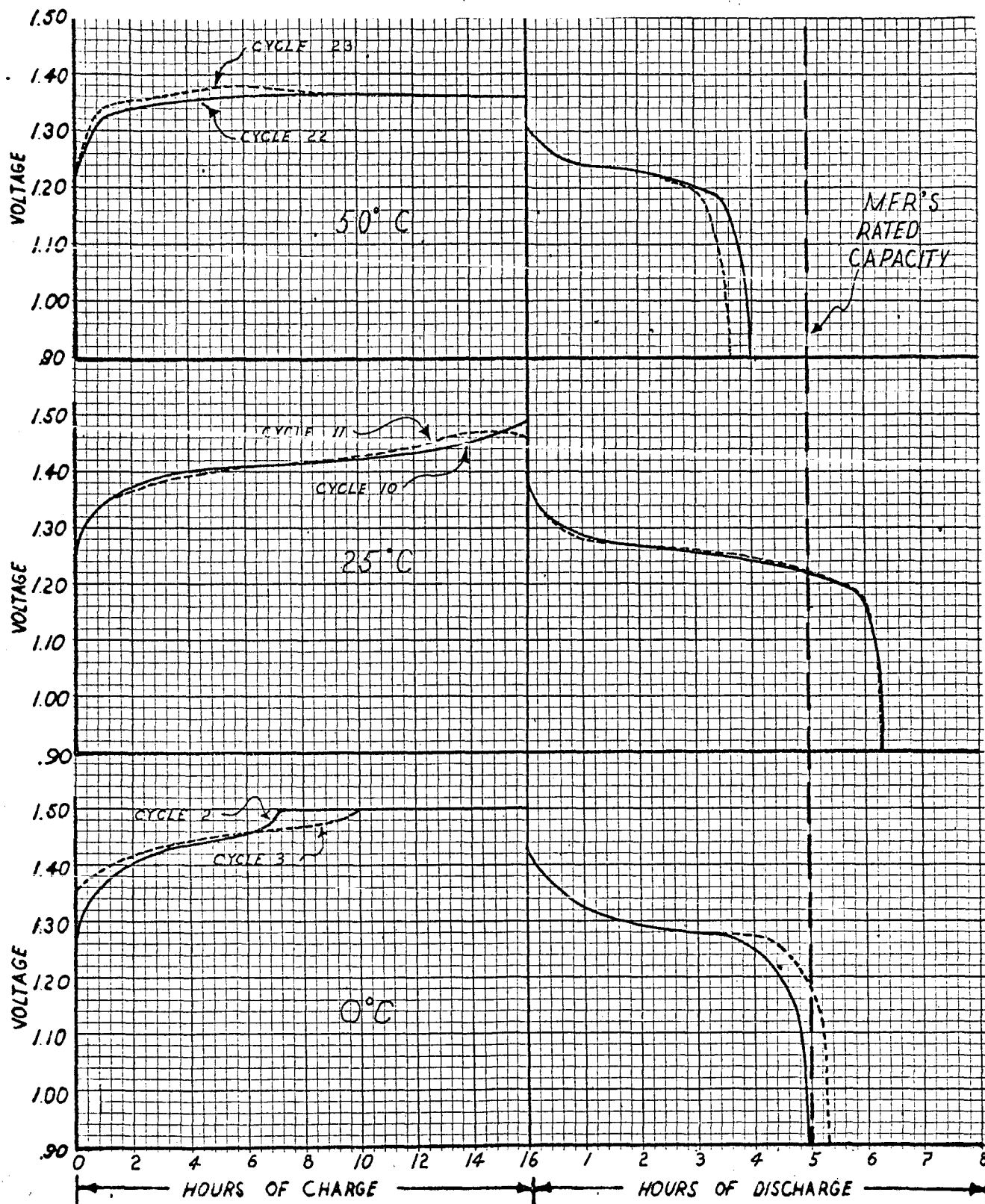
GOULD 20 A.H. CELL No. 72 NAD CRANE CAPACITY 25.2 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 3



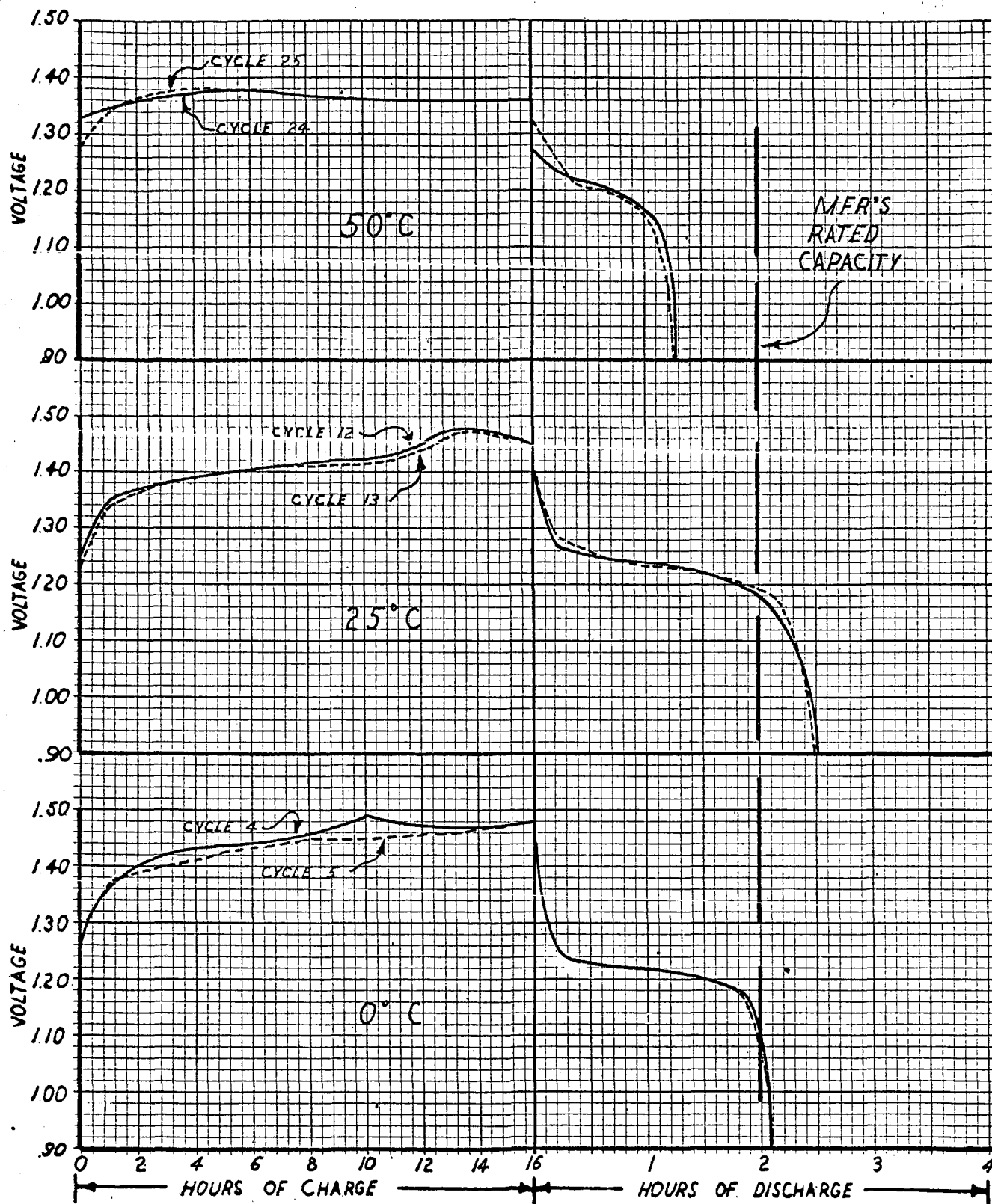
GOULD 20 A.H. CELL No. 13 MAD CRANE CAPACITY 28.2 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 4



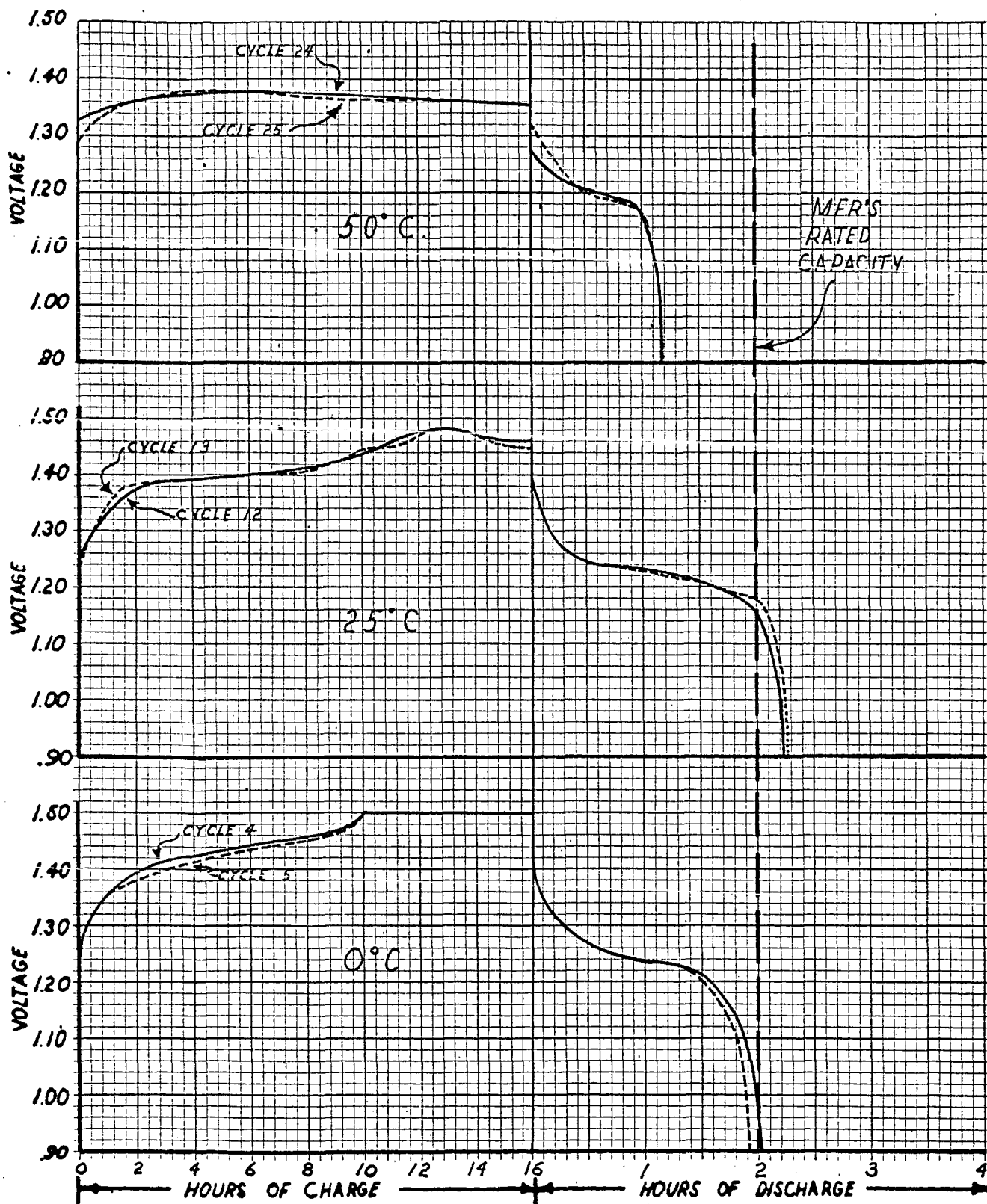
GOULD 20 A.H. CELL No. 27 NAD CRANE CAPACITY 28.3 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 5



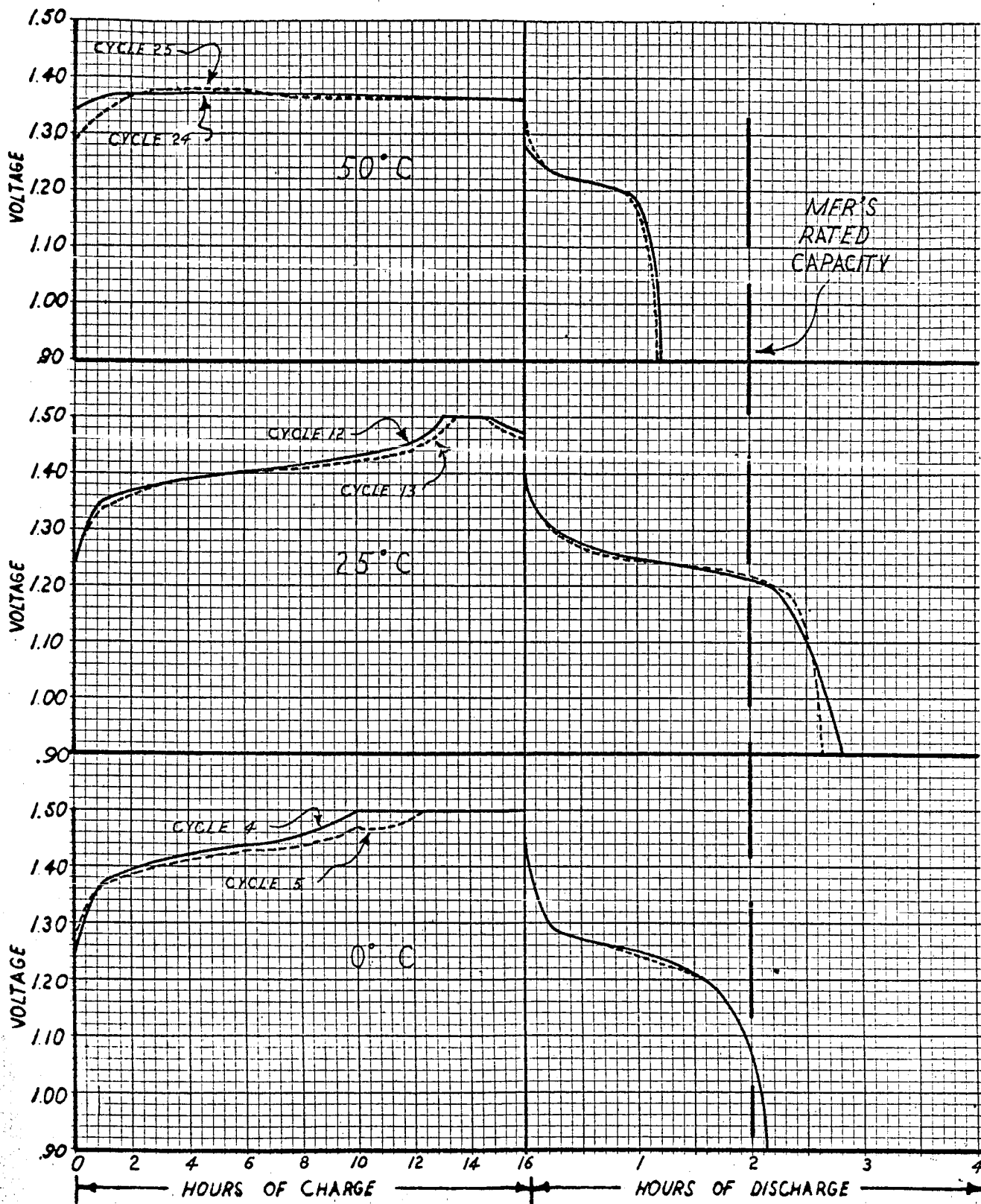
GOULD 20 A.H. CELL NO. 74 NAD CRANE CAPACITY 22.2 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 6



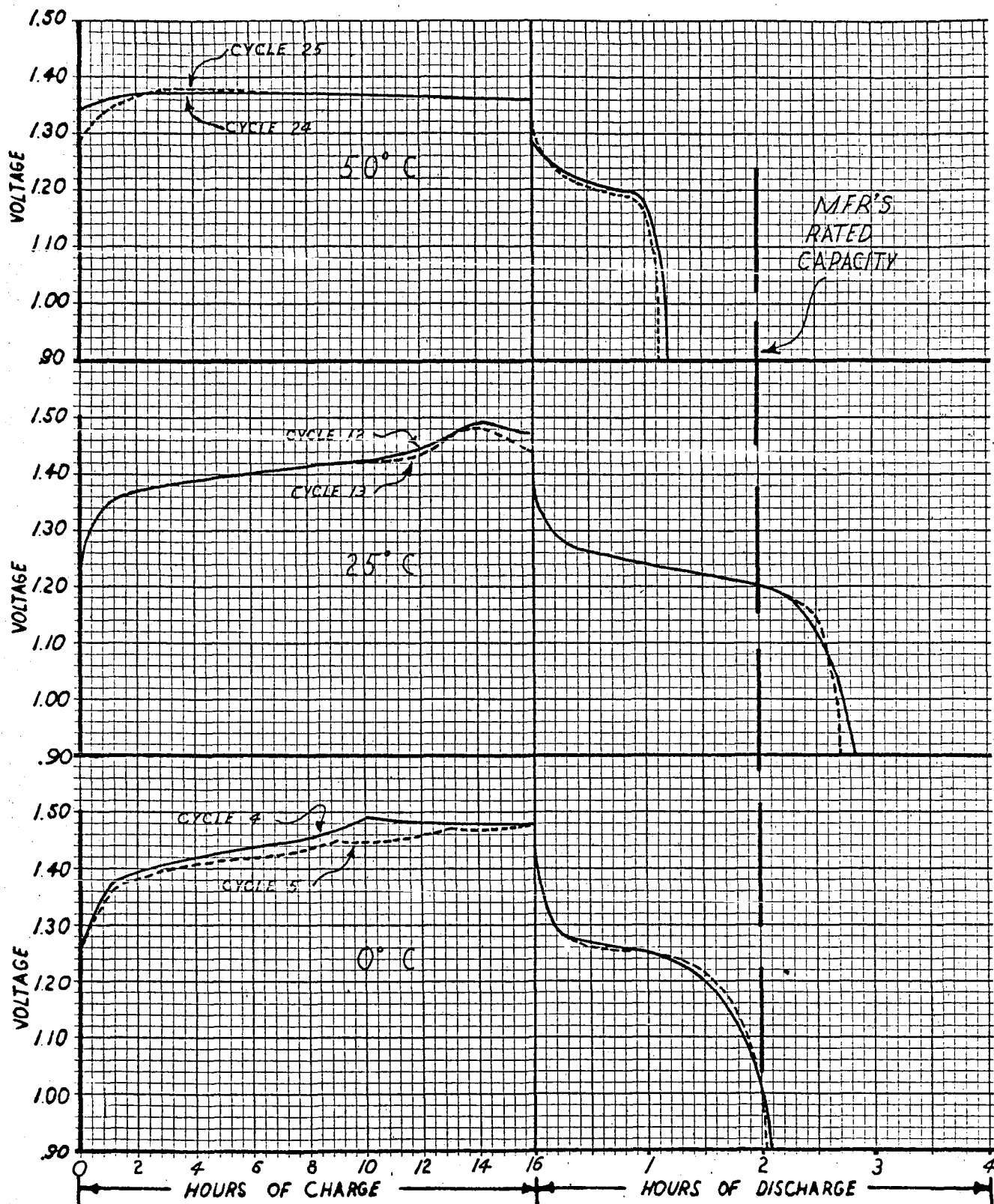
GOULD 20 A.H. CELL No. 77 NAD CRANE CAPACITY 22.3 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 7



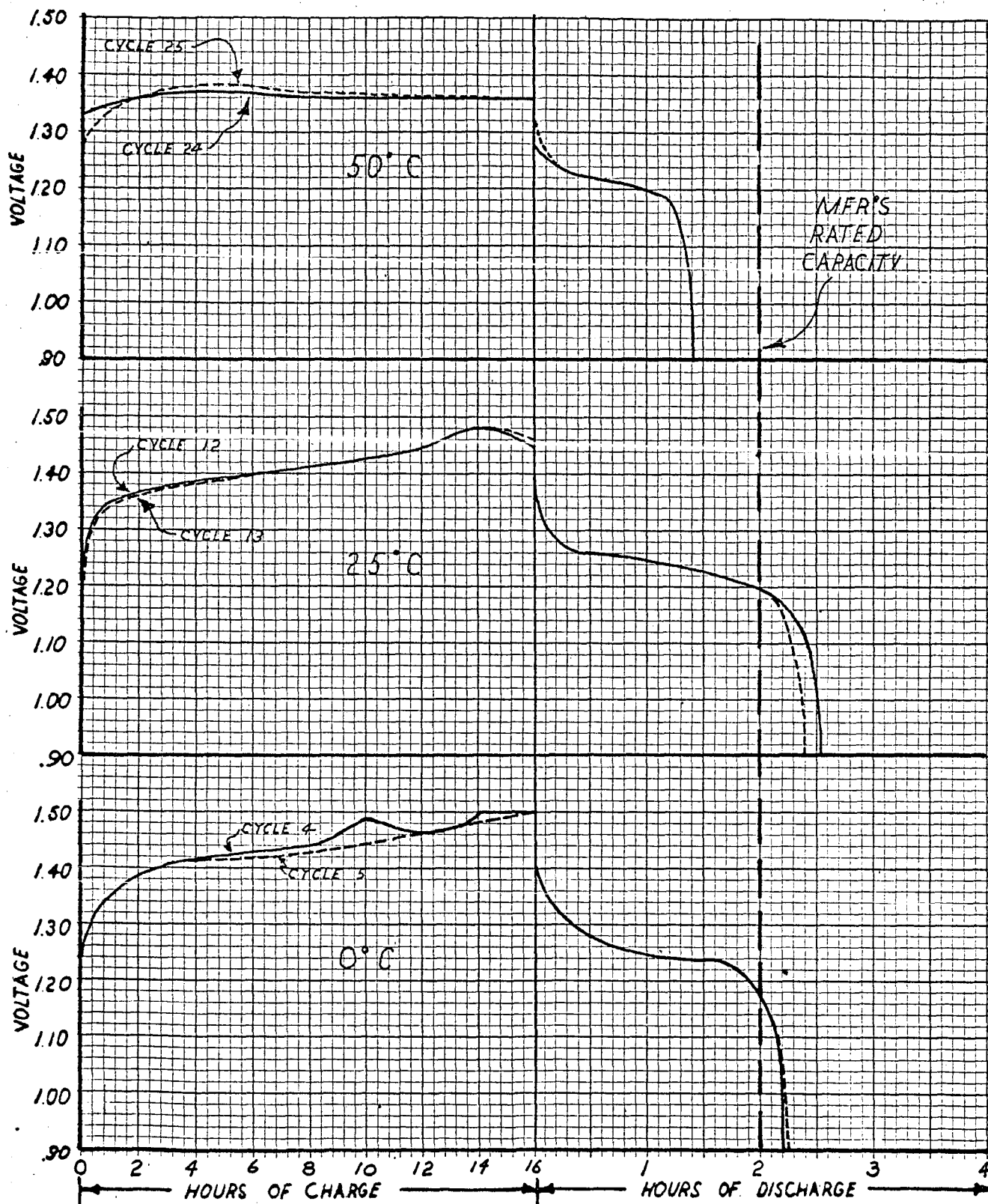
GOULD 20AH CELL No. 72 NAD CRANE CAPACITY 25.2 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 8



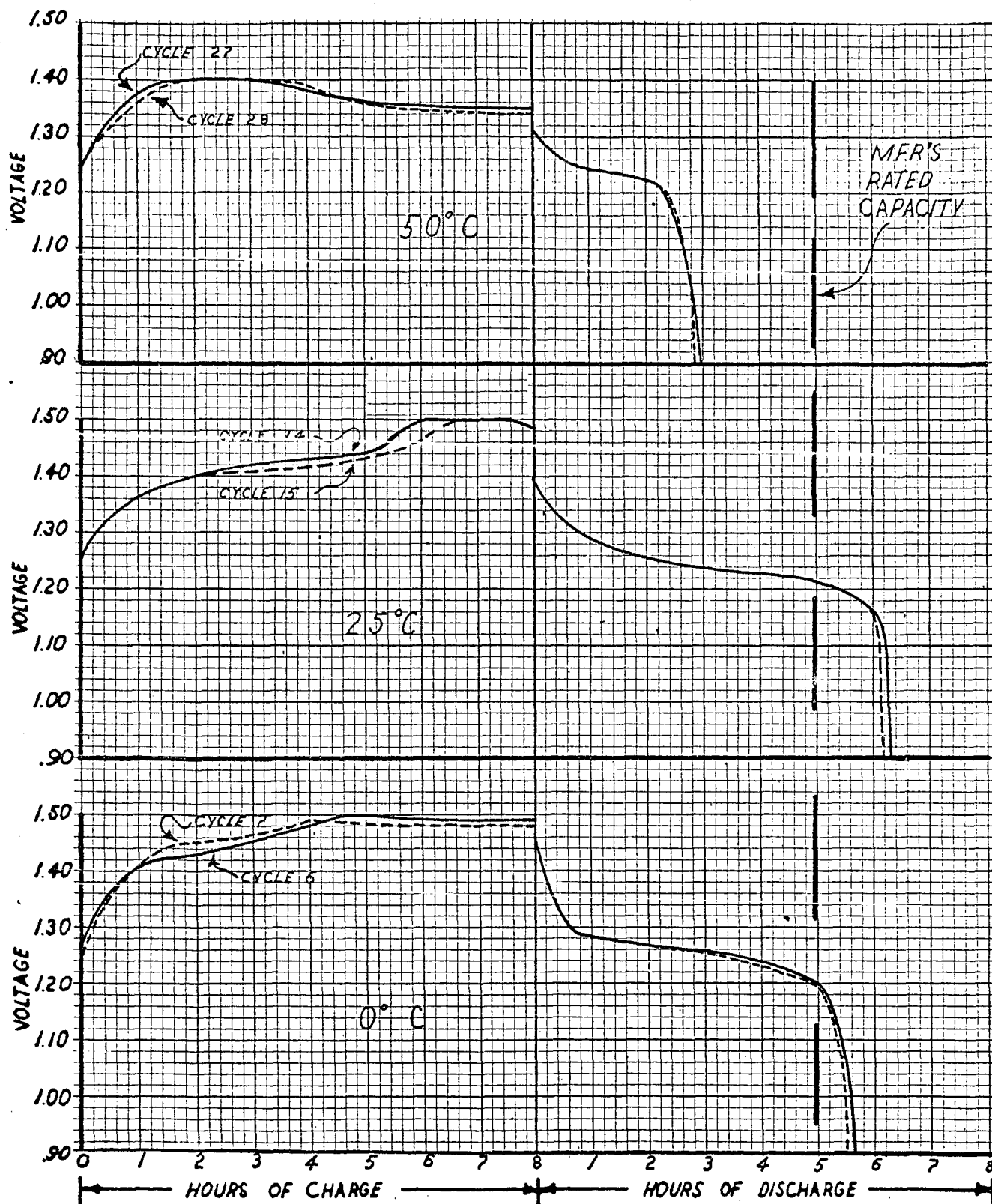
GOULD 20 A.H. CELL No. 13 NAD CRANE CAPACITY 28.2 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 100 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 9



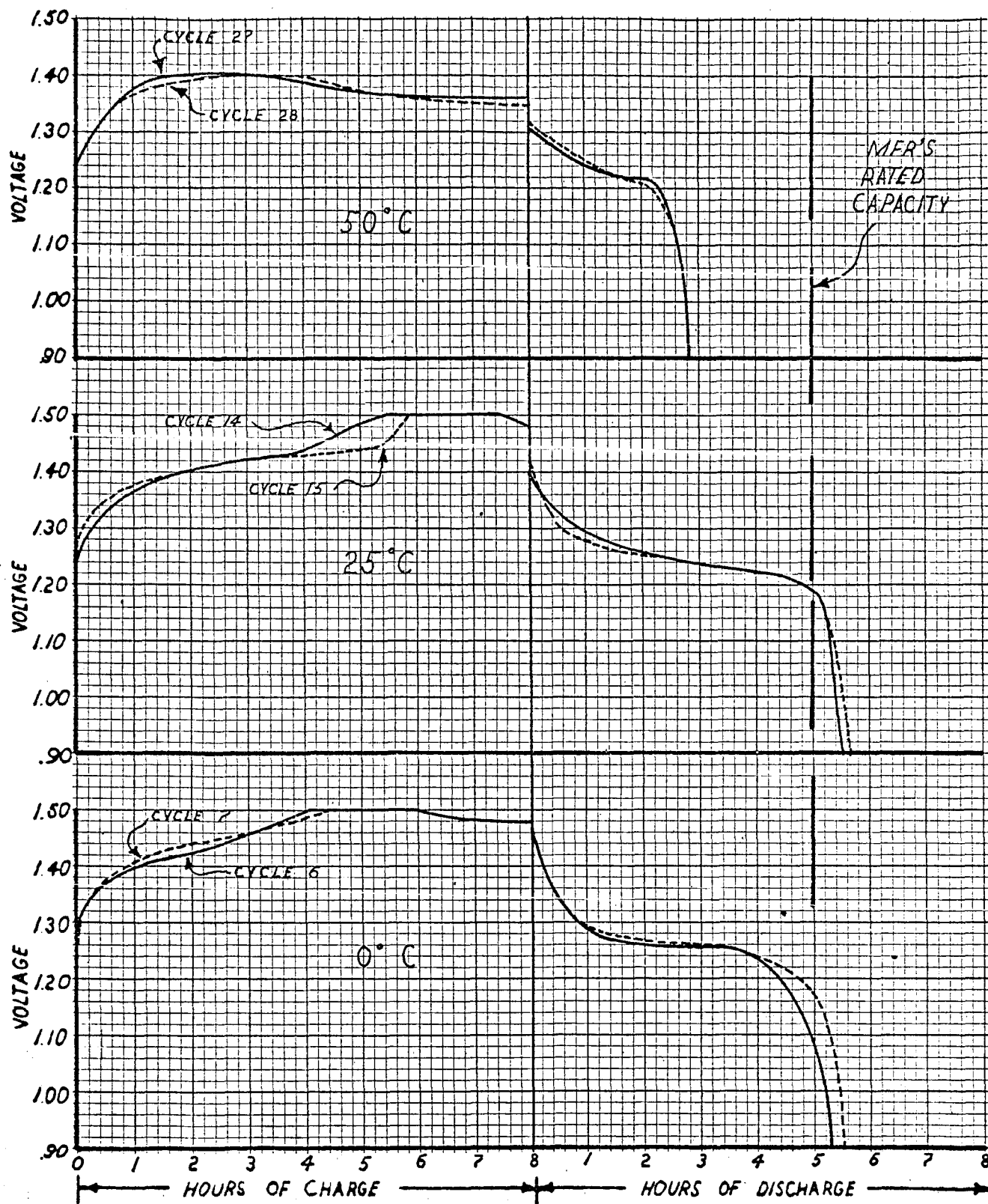
GOULD 20 A.H. CELL NO. 27 NAD CRANE CAPACITY 28.3 A.H.
 CHARGE CURRENT 2.0 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 10



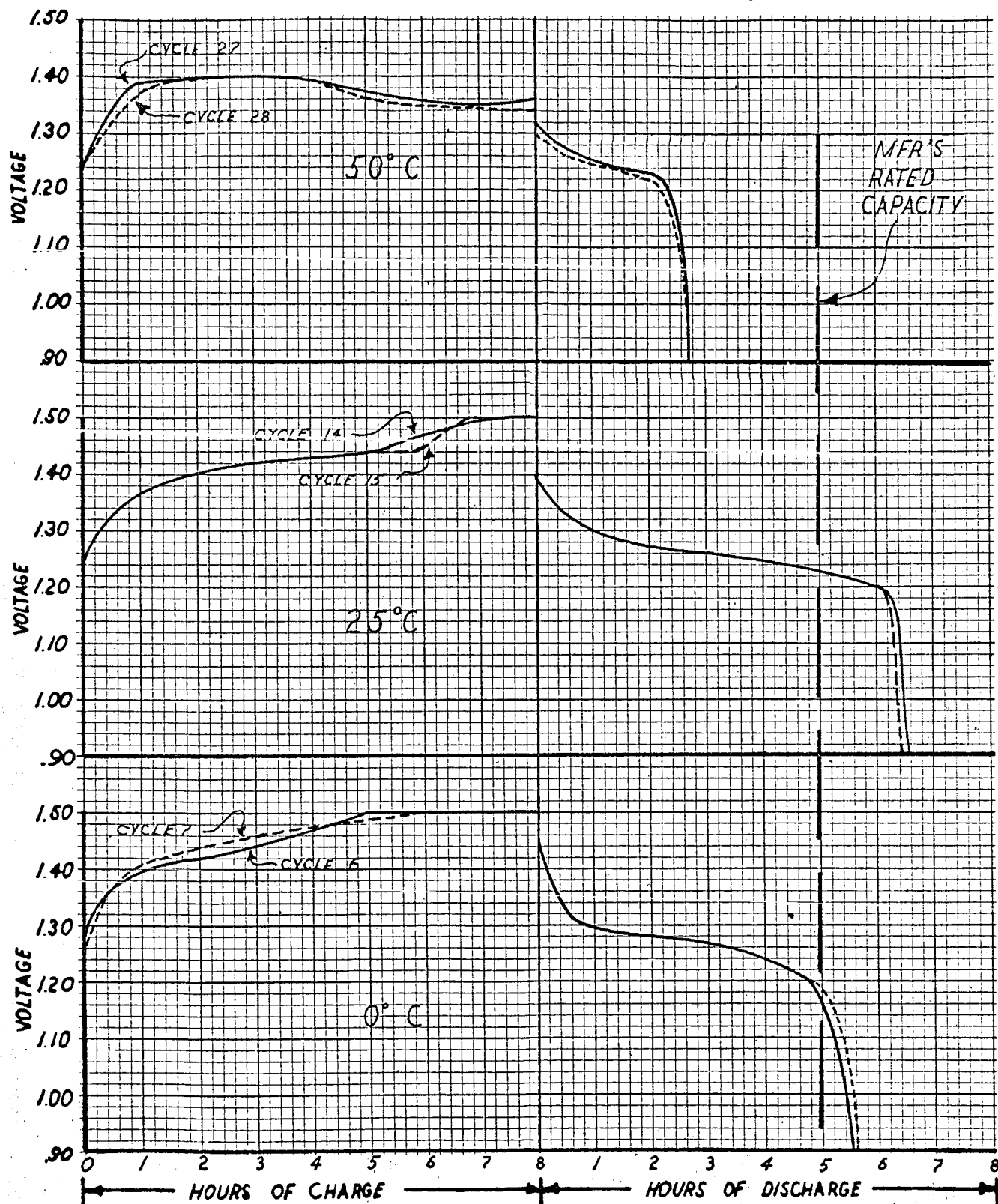
GOULD 20 A.H. CELL No. 74 NAD CRANE CAPACITY 22.2 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 11



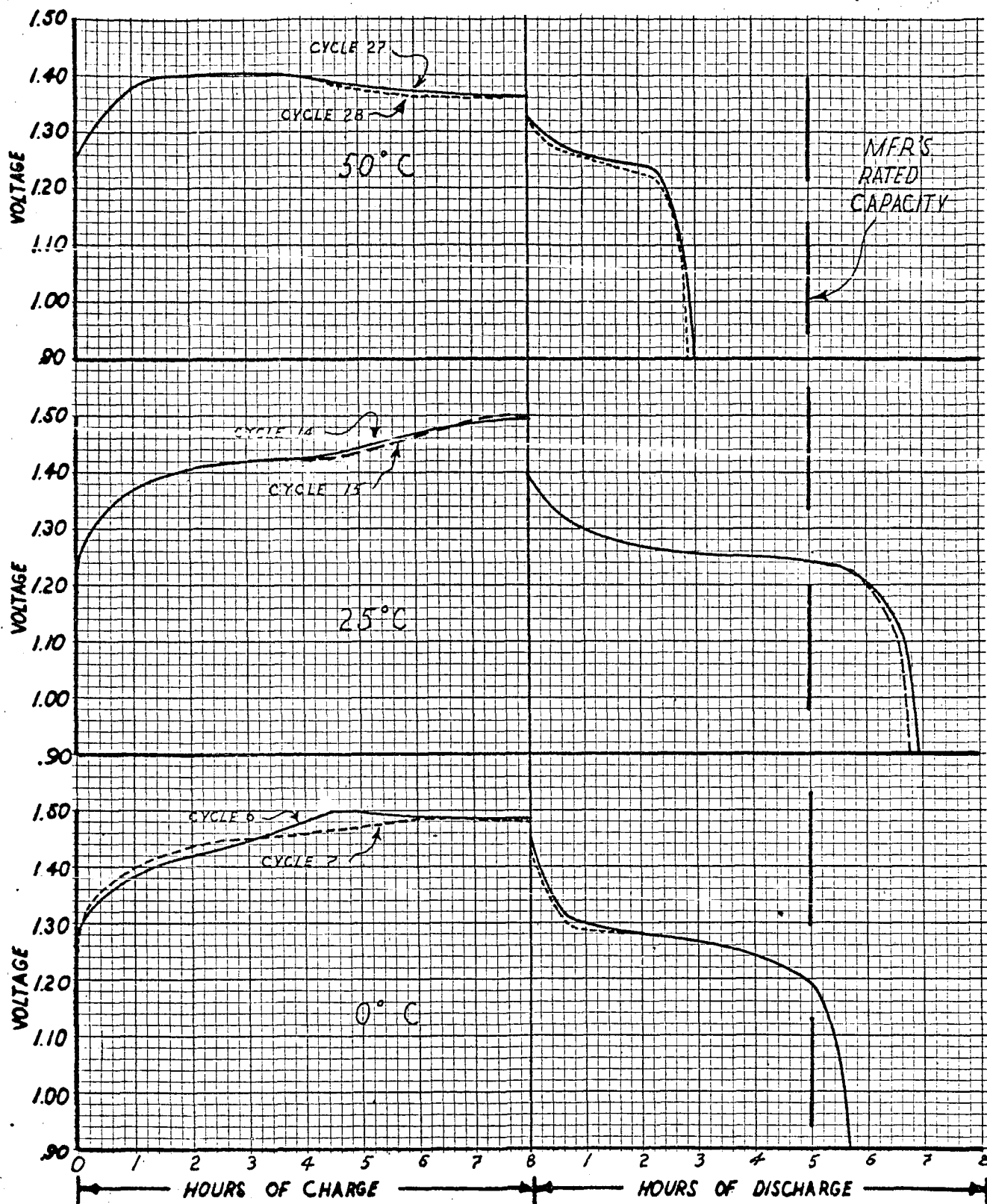
GOULD 20 A.H. CELL No. 77 NAD CRANE CAPACITY 22.3 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 12



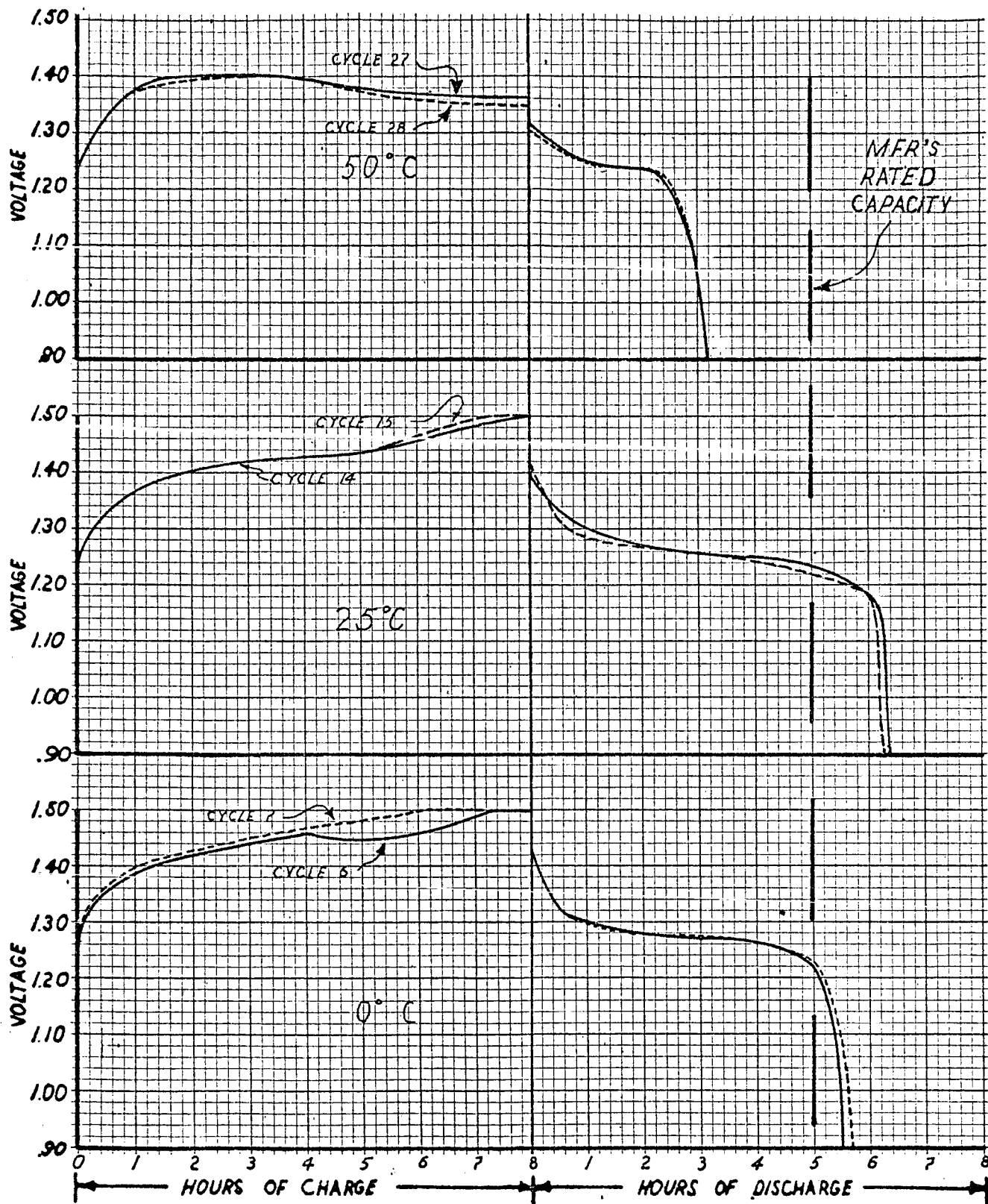
GOULD 20 A.H. CELL No. 72 NAD CRANE CAPACITY 25.2 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 13



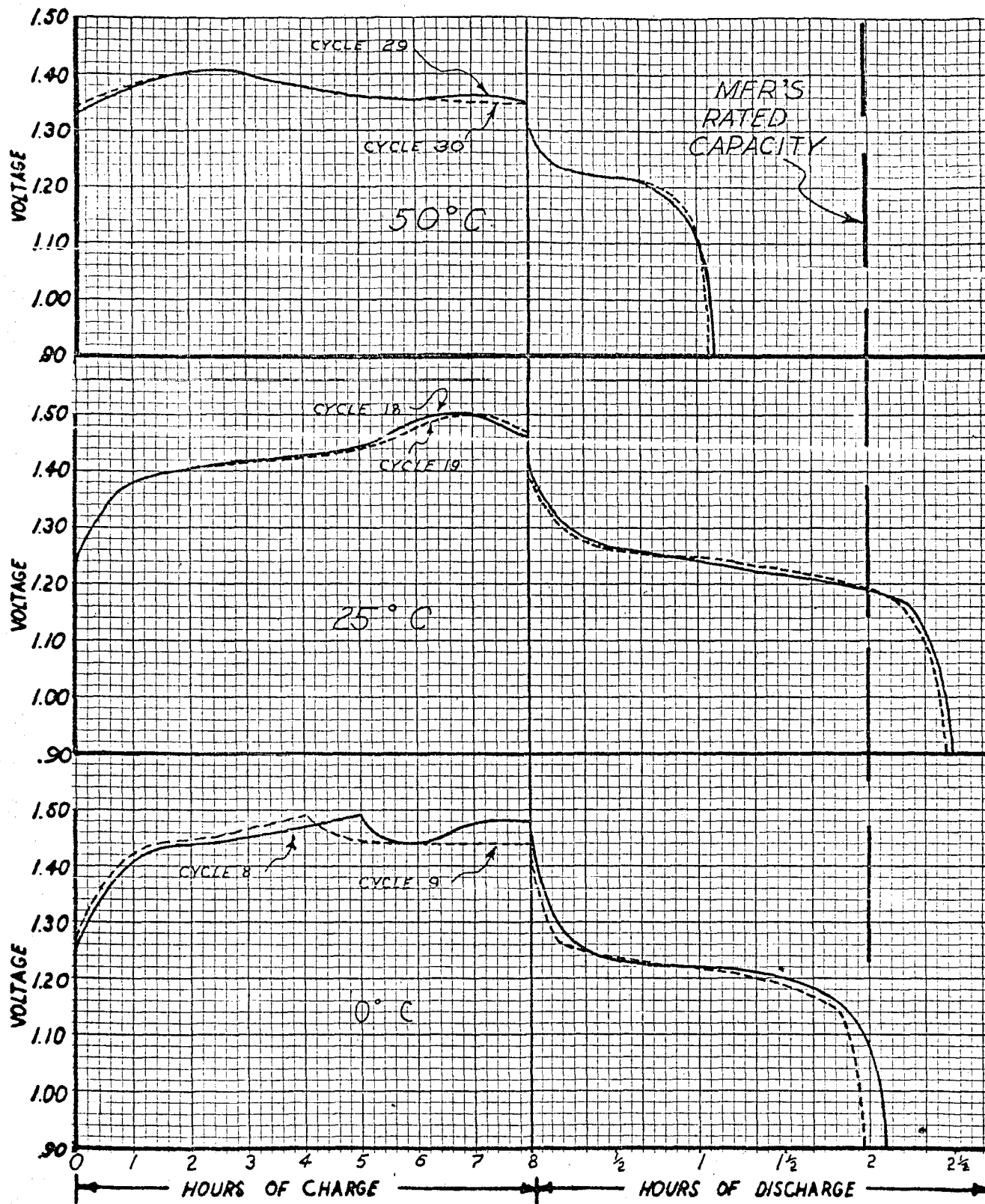
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 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 14



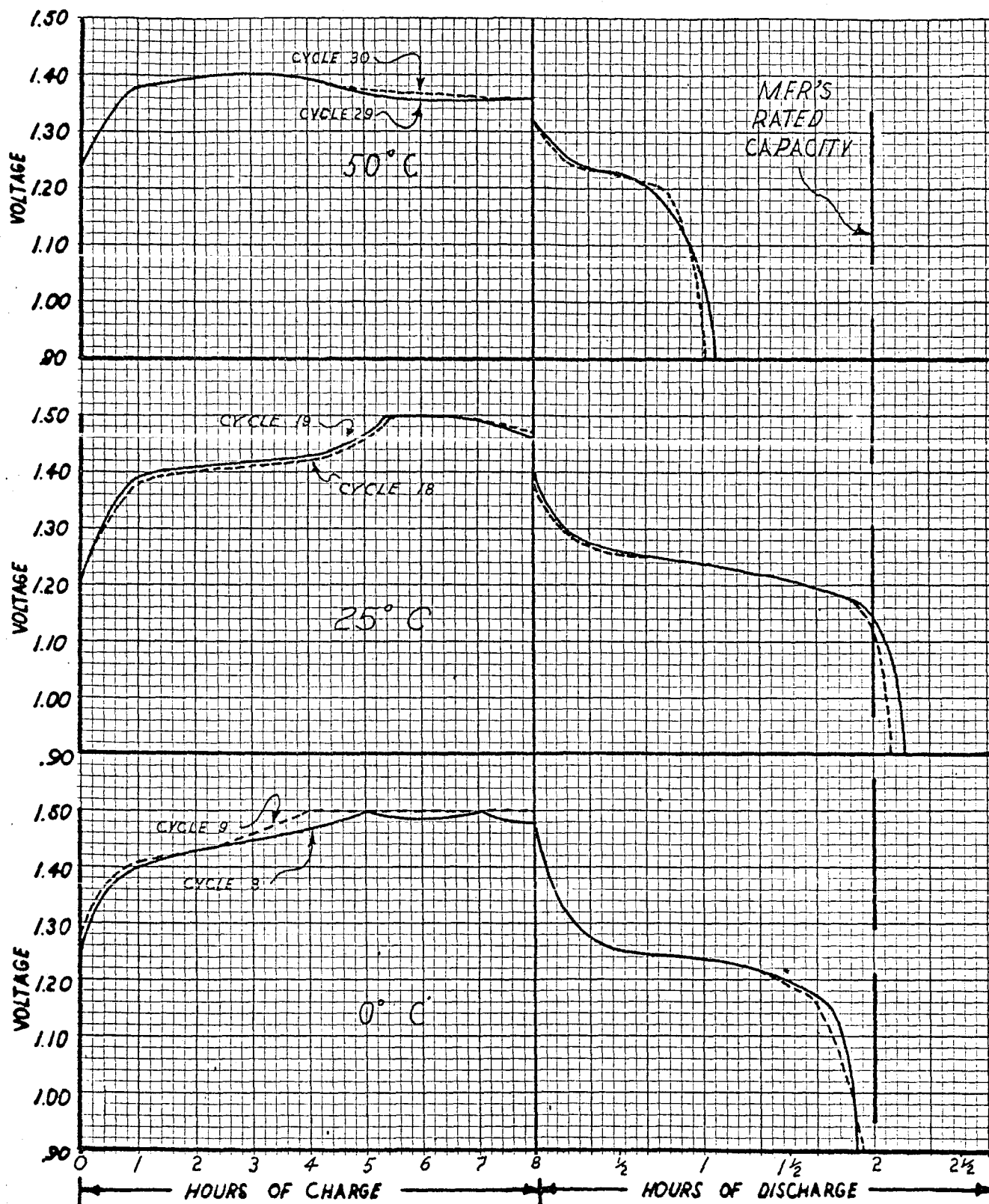
GOULD 20 A.H. CELL No. 27 NAD CRANE CAPACITY 28.3 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 4.0 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 15



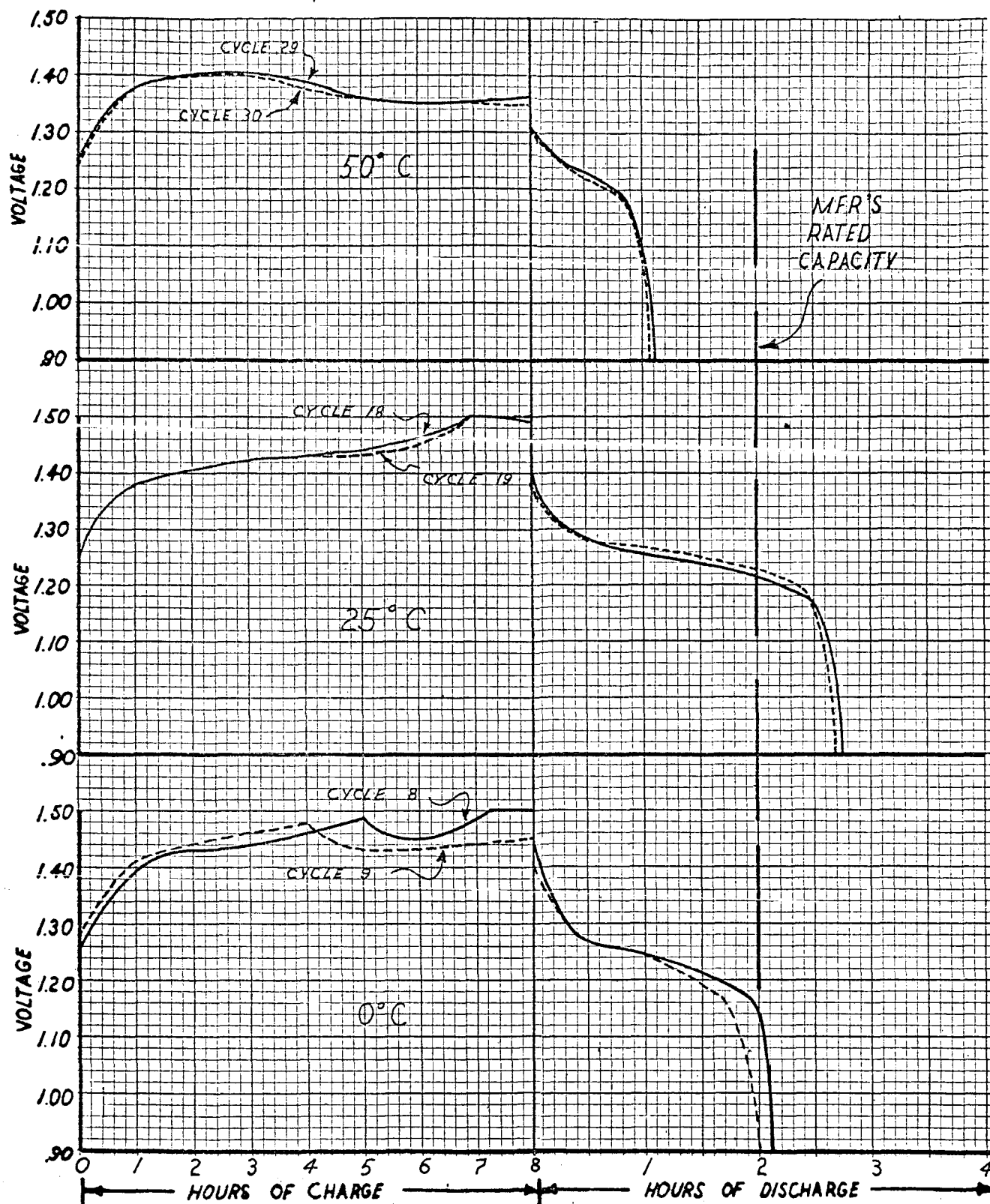
GOULD 20 A.H. CELL No. 74 NAD CRANE CAPACITY 22.2 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 16



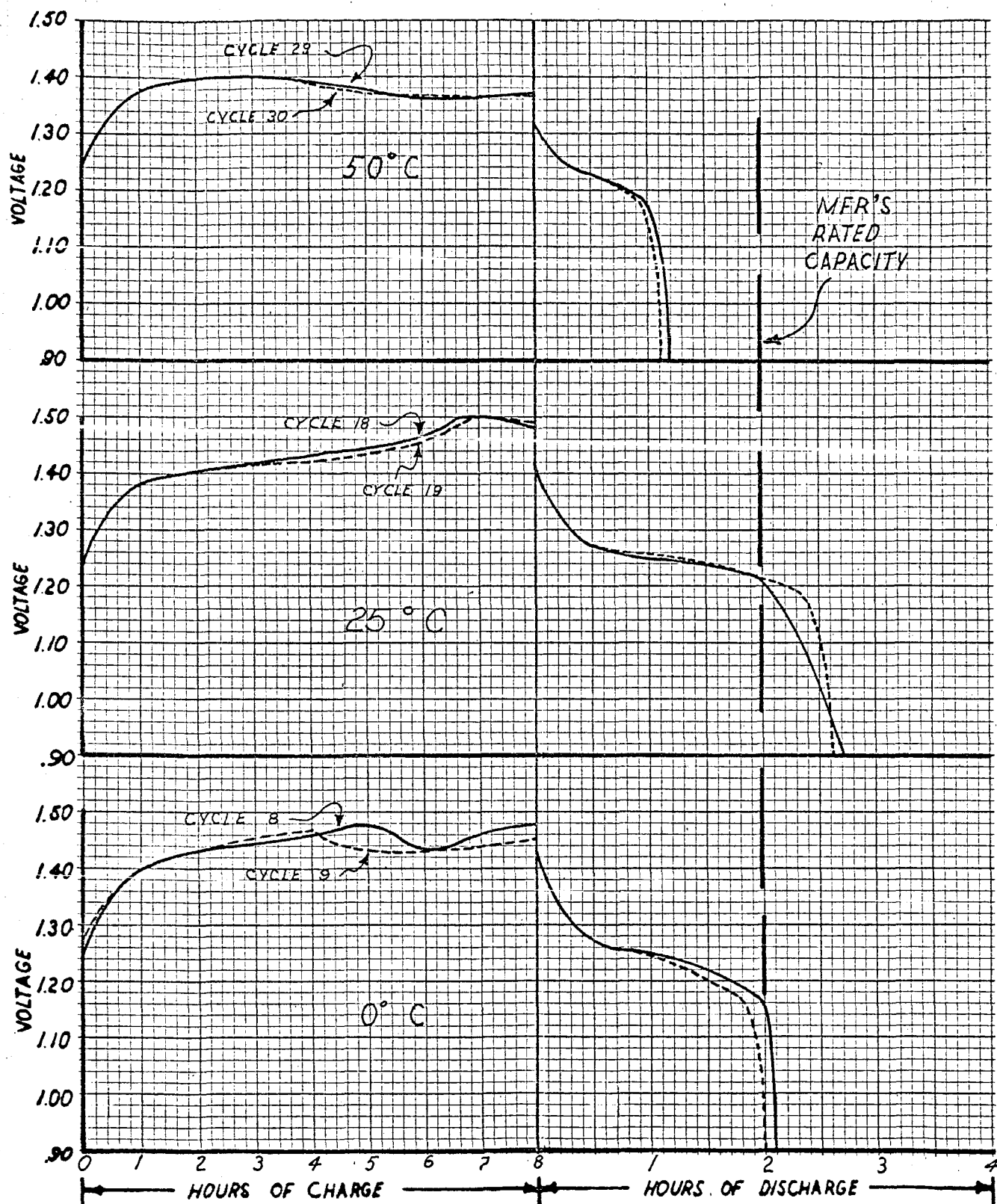
GOULD 20 A.H. CELL No. 77 NAD CRANE CAPACITY 22.3 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 17



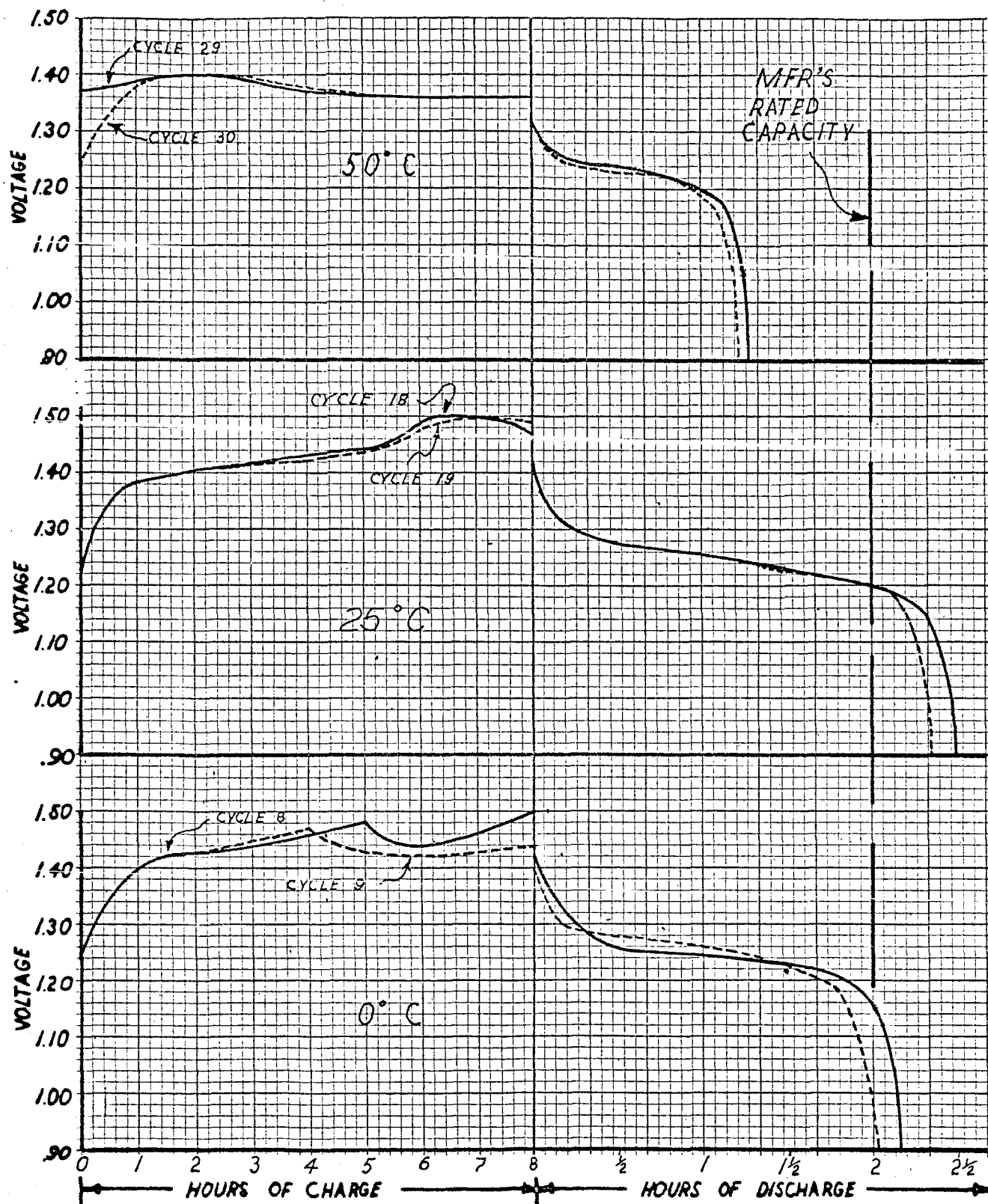
GOULD 20 A.H. CELL No. 72 NAD CRANE CAPACITY 25.2 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 18



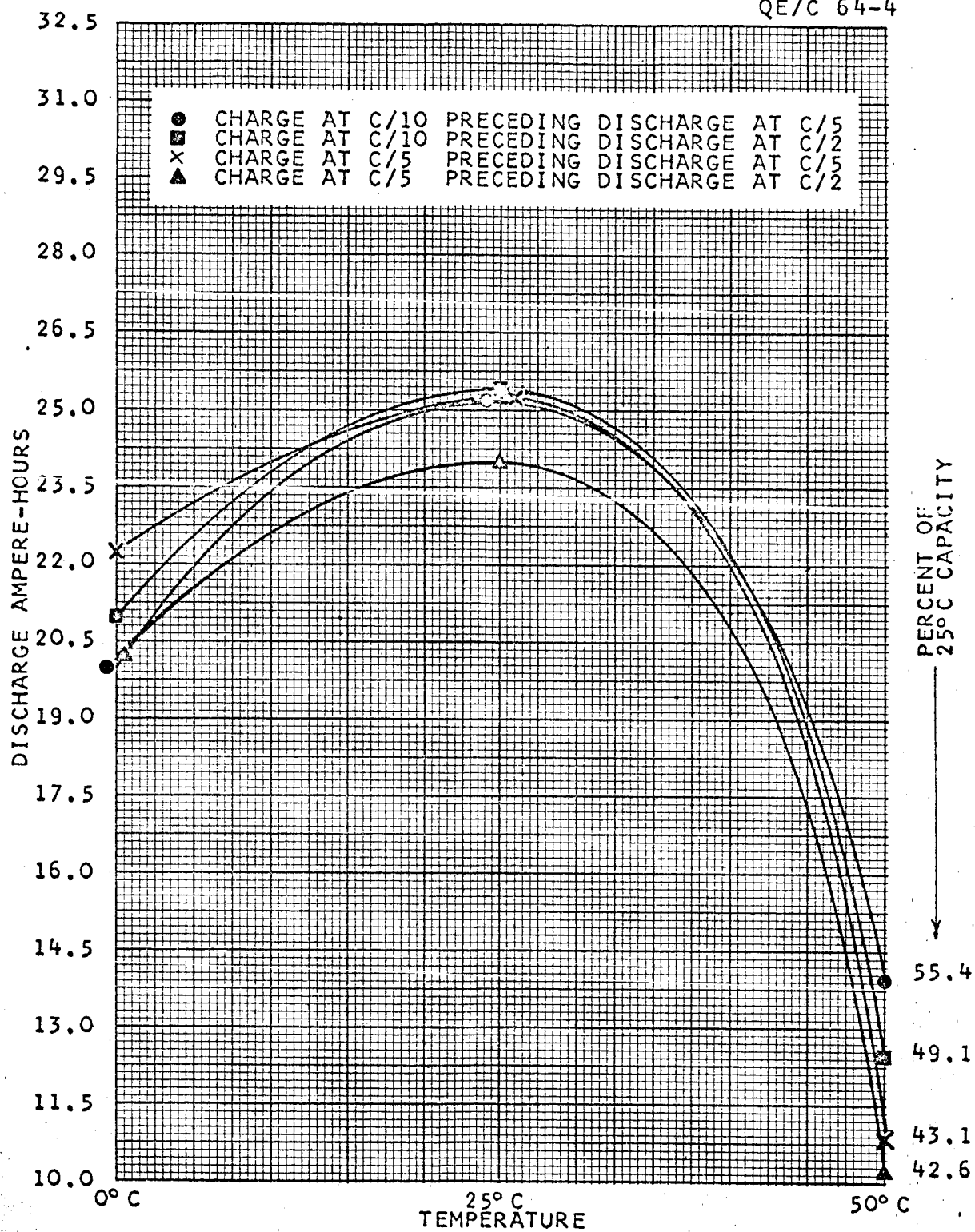
GOULD 20 A.H. CELL No. 13 NAD CRANE CAPACITY 28.2 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 19

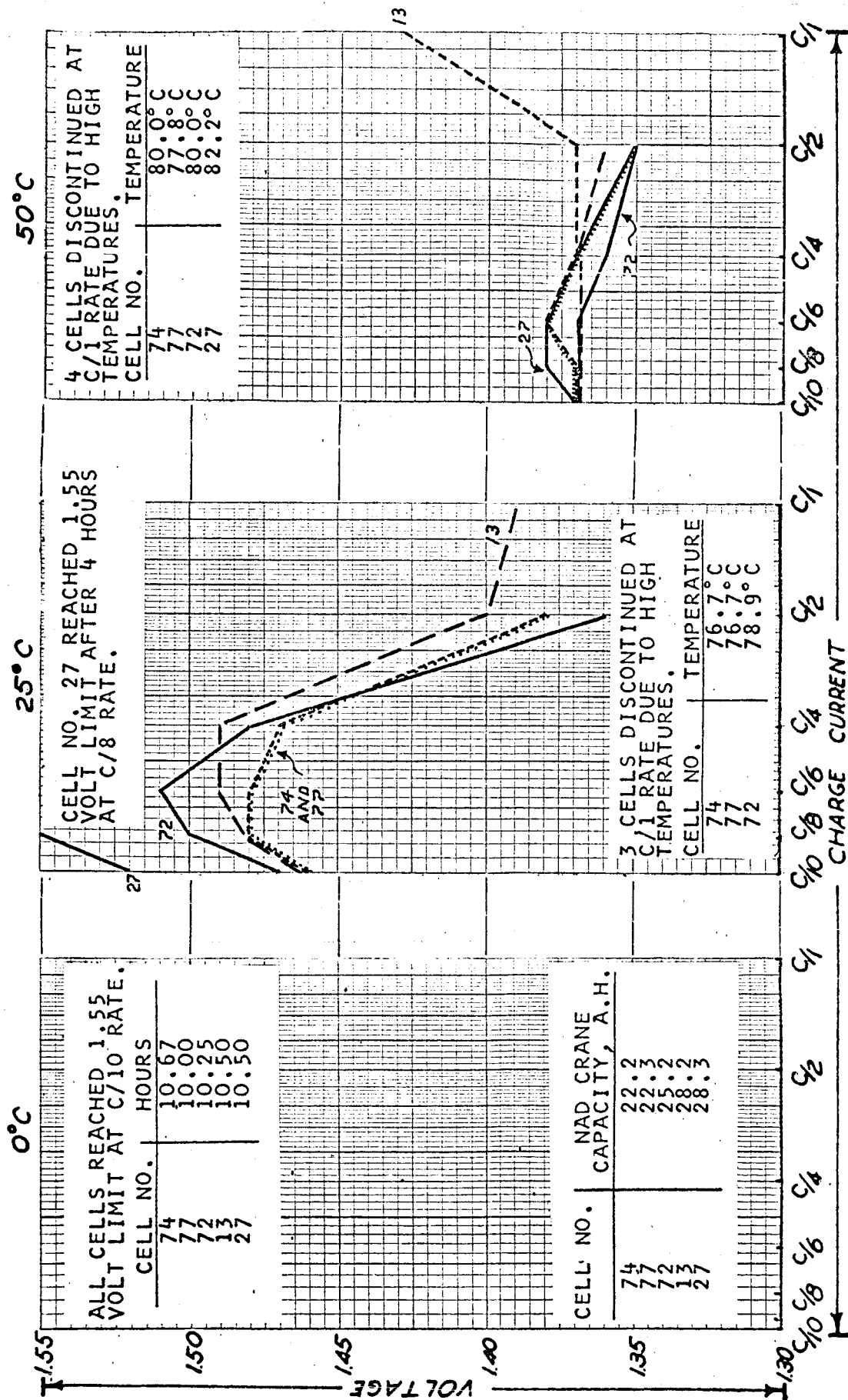


GOULD 20 A.H. CELL No. 27 NAD CRANE CAPACITY 28.3 A.H.
 CHARGE CURRENT 4.0 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
 DISCHARGE CURRENT 10.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 20

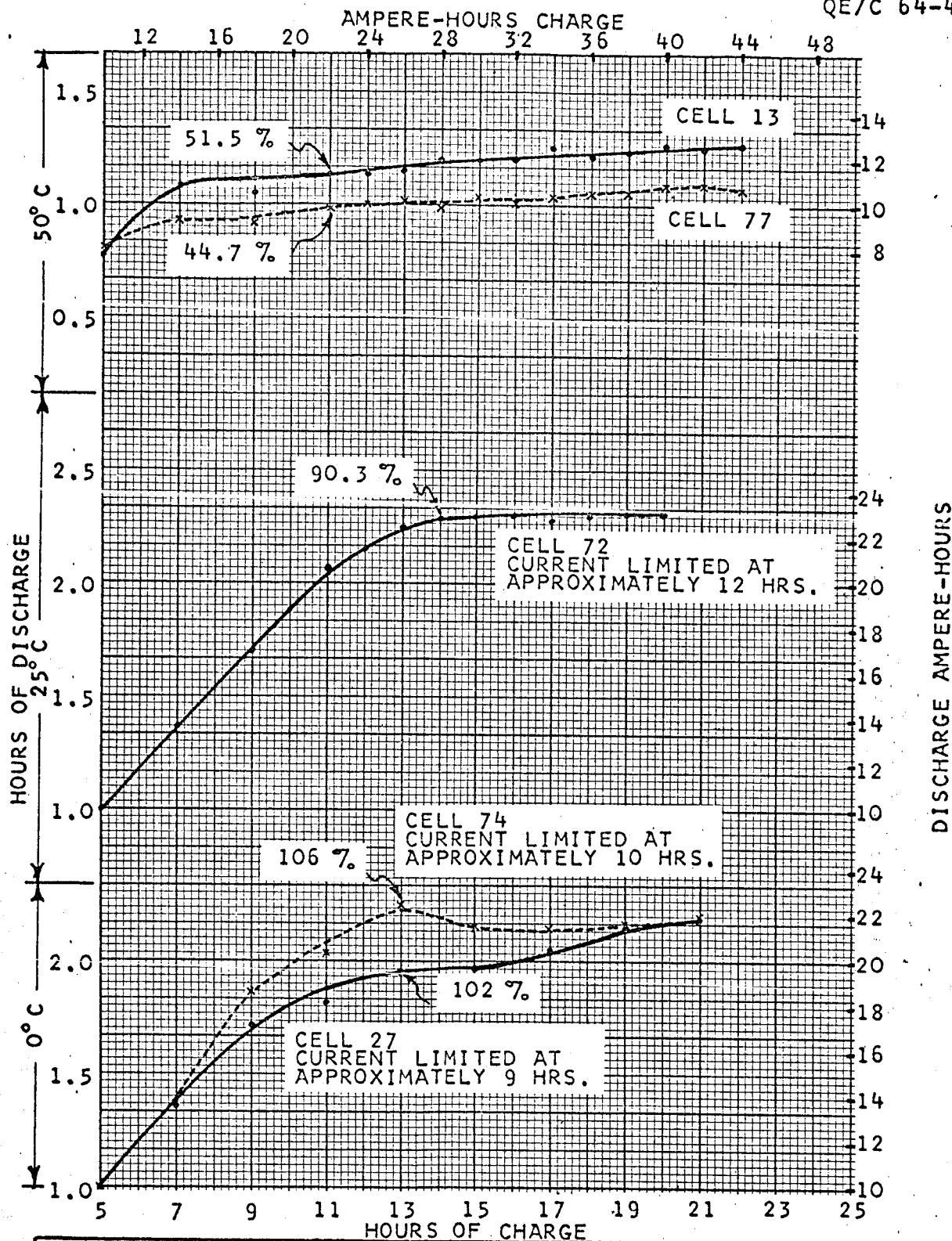


GOULD 20 A.H.
 AVERAGE CELL OUTPUT VS TEMPERATURE
 (FROM FIGURES 1 THROUGH 20)



GOULD 20 A.H.
OVERCHARGE CHARACTERISTICS

FIGURE 22



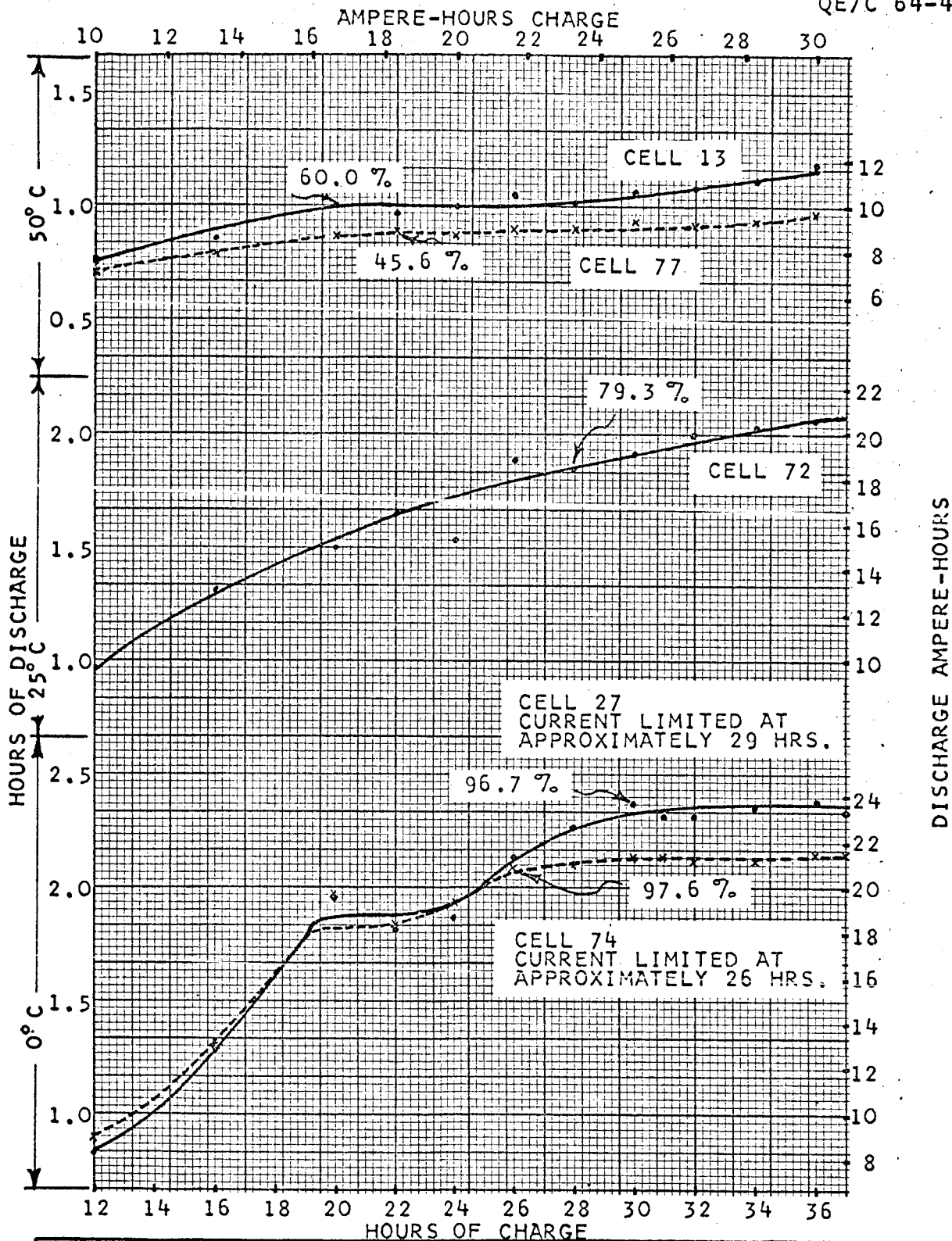
CHARGING EFFICIENCY

GOULD 20 A.H.

CHARGE CURRENT 2.0 A. - C/10
VOLTAGE LIMITED TO 1.50 V.DISCHARGE CURRENT 10.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
74	22.2
77	22.3
72	22.2
13	28.2
27	28.3

FIGURE 23



CHARGING EFFICIENCY

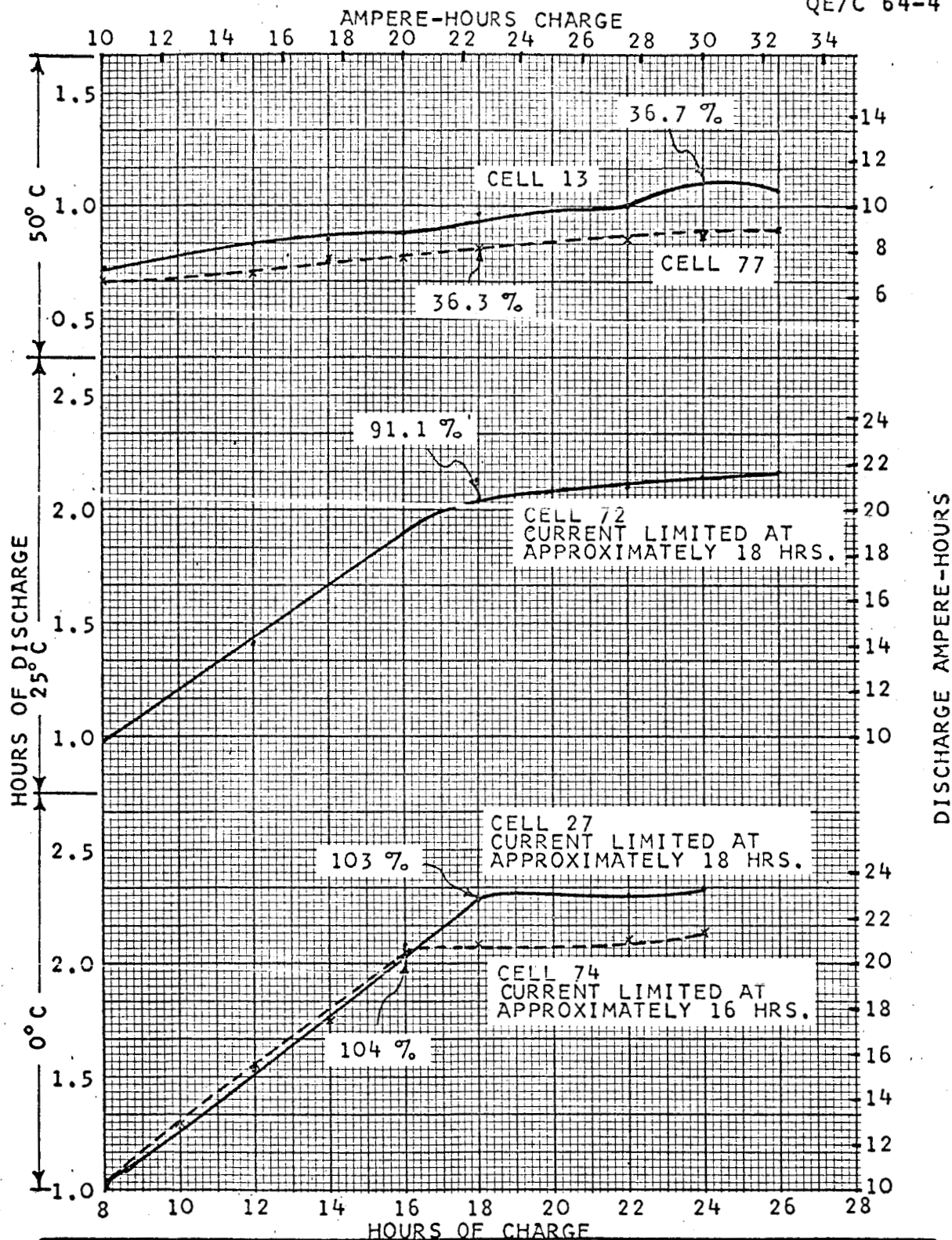
GOULD 20 A.H.

CHARGE CURRENT 833 MA. - C/24
VOLTAGE LIMITED TO 1.50 V.

DISCHARGE CURRENT 10.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
74	22.2
77	22.3
72	25.2
13	28.2
27	28.3

FIGURE 24



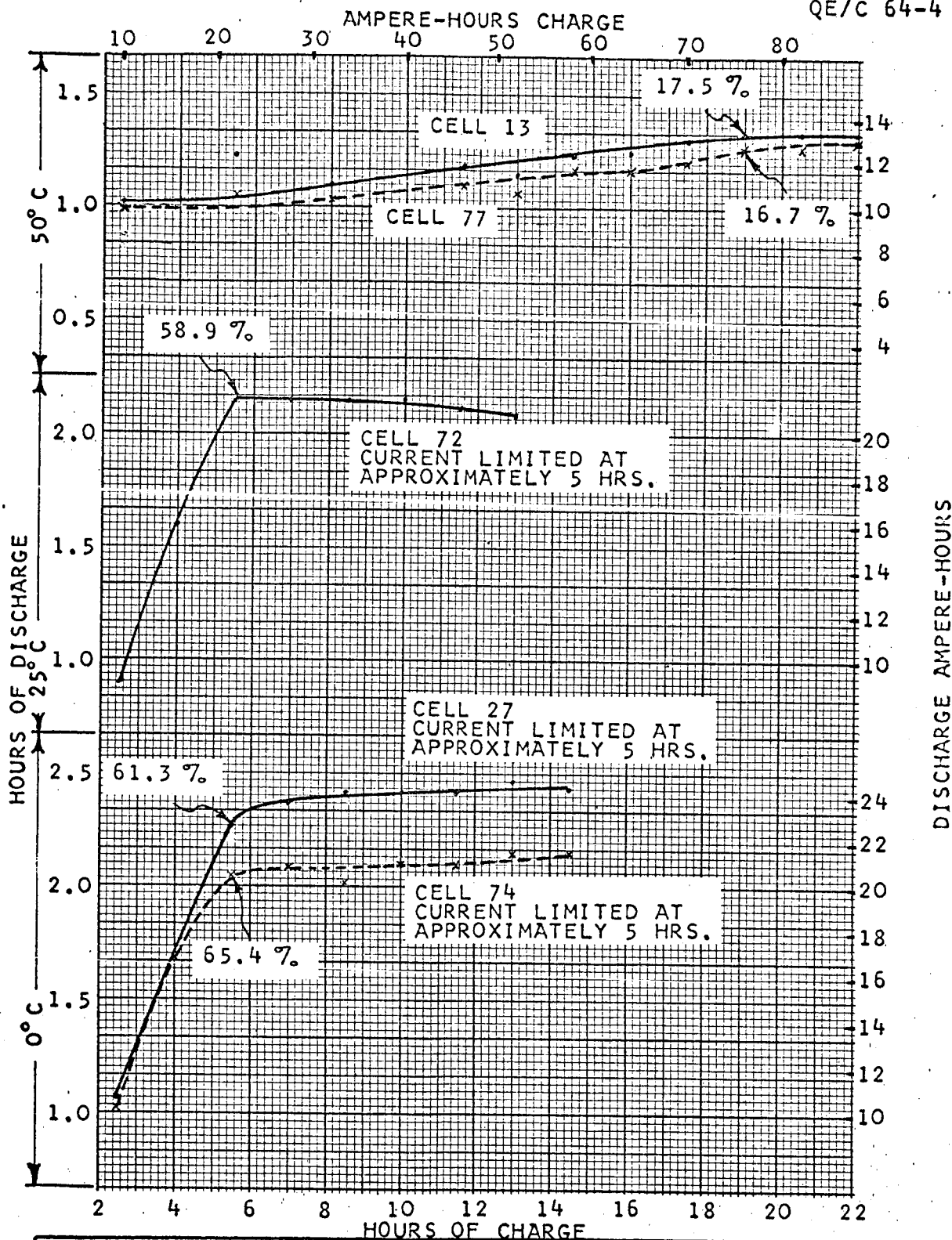
CHARGING EFFICIENCY

GOULD 20 A.H.

CHARGE CURRENT 1.25 A. - C/16
VOLTAGE LIMITED TO 1.50 V.DISCHARGE CURRENT 10.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

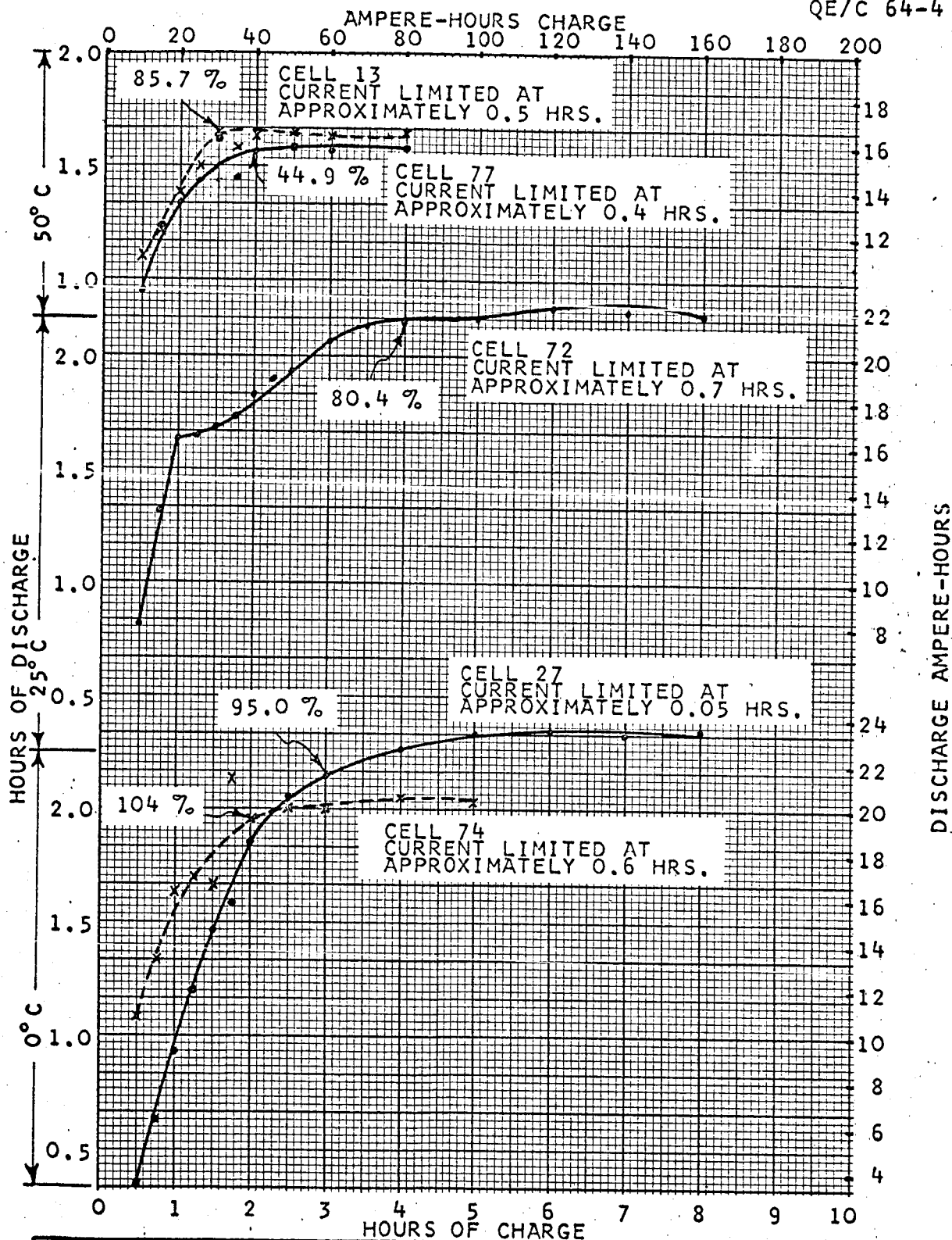
CELL NO.	NAD CRANE CAPACITY, A.H.
74	22.2
77	22.3
72	25.2
13	28.2
27	28.3

FIGURE 25



CHARGING EFFICIENCY	
GOULD 20 A.H.	
CHARGE CURRENT 4.0 A. - C/5	
VOLTAGE LIMITED TO 1.50 V.	
DISCHARGE CURRENT 10.0 A. - C/2	
CUTOFF VOLTAGE 1.0 V.	
CELL NO.	NAD CRANE CAPACITY, A.H.
74	22.2
77	22.3
72	25.2
13	28.2
27	28.3

FIGURE 26



CHARGING EFFICIENCY	
GOULD 20 A.H.	
CHARGE CURRENT 20.0 A. - C/1	
VOLTAGE LIMITED TO 1.50 V.	
DISCHARGE CURRENT 10.0 A. - C/2	
CUTOFF VOLTAGE 1.0 V.	
CELL NO.	NAD CRANE CAPACITY, A.H.
74	22.2
77	22.3
72	25.2
13	28.2
27	28.3

FIGURE 27

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